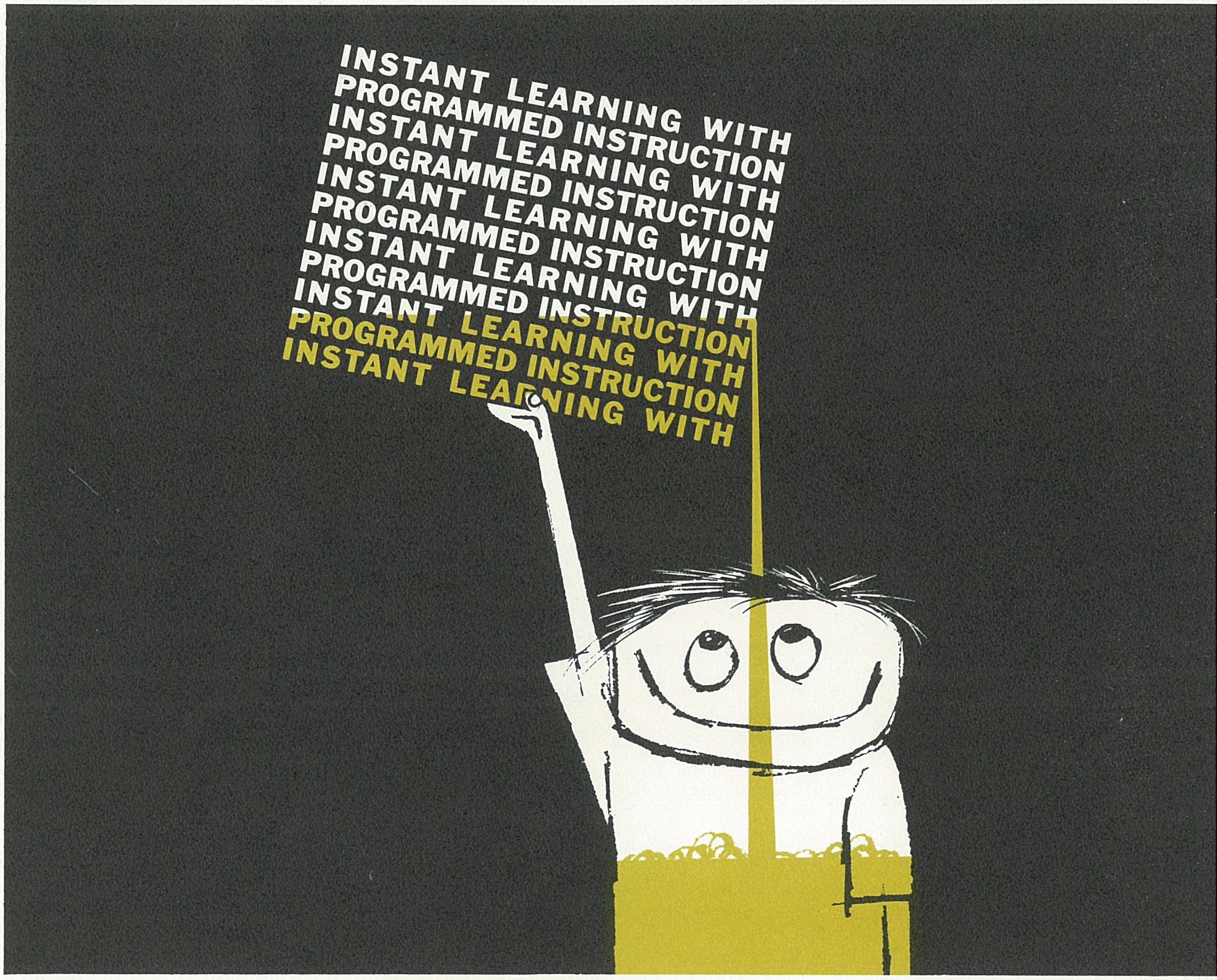
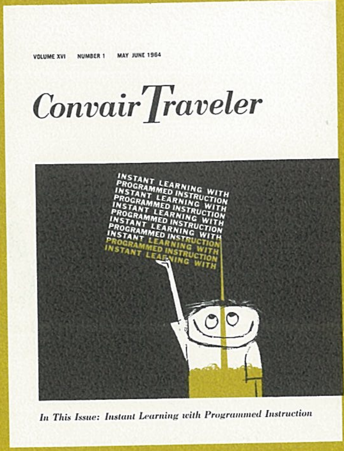
VOLUME XVI NUMBER 1 MAY | JUNE 1964

# Convair Traveler



*In This Issue: Instant Learning with Programmed Instruction*


VOLUME XVI NUMBER 1 MAY JUNE 1964
Convair Traveler
INSTANT LEARNING WITH PROGRAMMED INSTRUCTION
In This Issue: Instant Learning with Programmed Instruction

OUR COVER
A quotation by Petrarch, "Books have led some to learning and others to madness," could very well apply to Willis Goldsmith's cartoons. We'd like to add a quotation by Stephens, "If a person desires to be a humorist, it is necessary that the people around him shall be at least as wise as he is, otherwise his humor will not be comprehended." Layout on Ermeto fittings by Geo. Paul.

# Convair Traveler

**VOLUME XVI NUMBER 1 MAY/JUNE 1964**

MANAGER, CUSTOMER SERVICE—**O. W. HARPER**
CHIEF ENGINEERING SERVICE—**L. J. BORDELON**
CHIEF, FIELD SERVICE—**R. E. SOMMERS**
CHIEF, SERVICE PARTS—**J. DOIG**
CHIEF, TECHNICAL PUBLICATIONS—
**H. R. KENNEDY**
EDITOR—**GERTRUDE S. HUNTER**

## IN THIS ISSUE

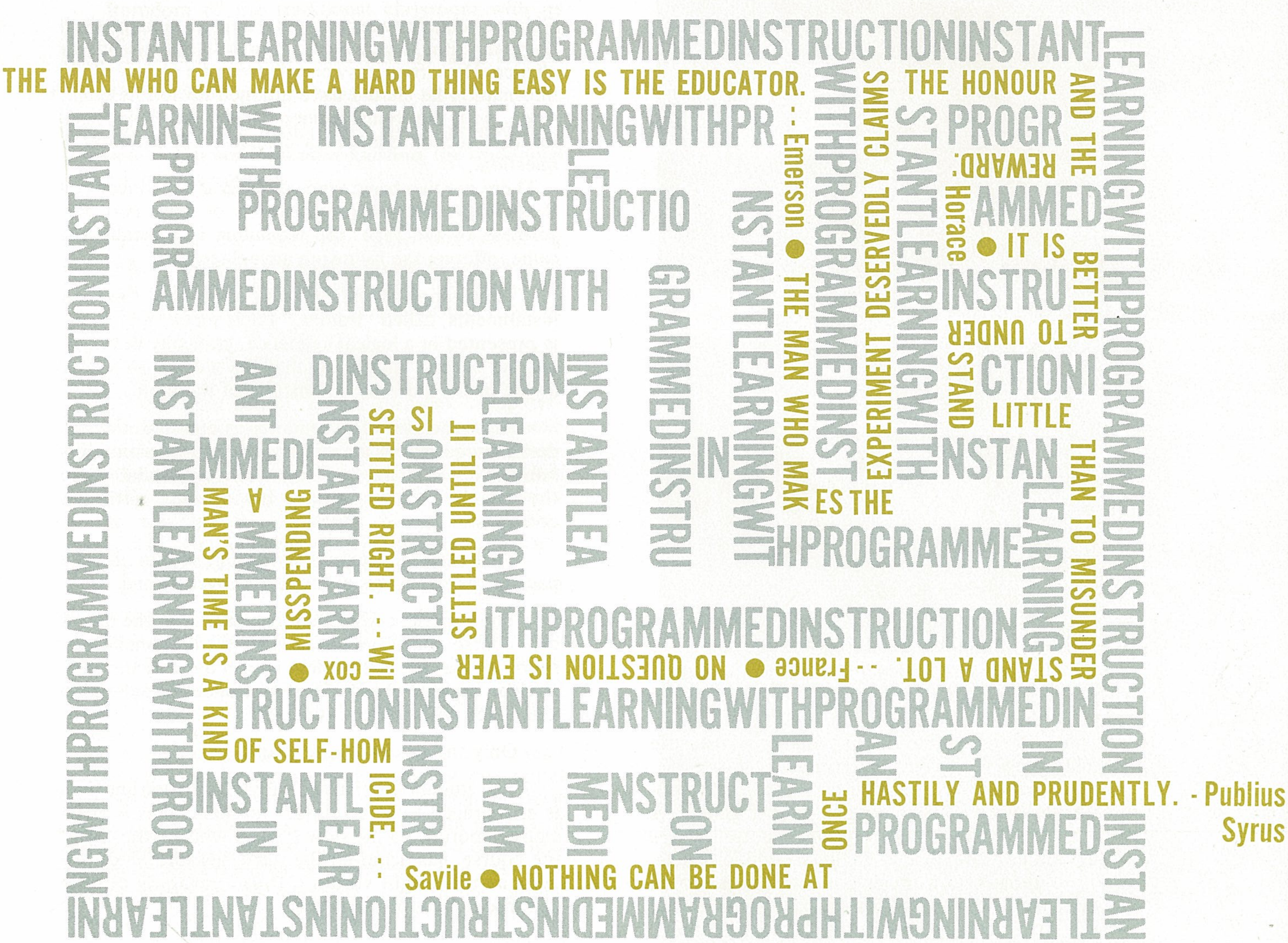
**PAGE 3**
INSTANT LEARNING WITH PROGRAMMED INSTRUCTION

**PAGE 10**
MS(ER) FLARELESS TUBE FITTINGS

A digest of operation and service published monthly by the Technical Publications Section of GD|Convair, primarily for the interest of Convair operators. Permission to reprint any information from this periodical must be obtained from the Chief of Technical Publications, General Dynamics|Convair, San Diego 12, Calif. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without the specific approval of their cognizant organization.

COPYRIGHT 1964

**GENERAL DYNAMICS|CONVAIR**


INSTANT LEARNING WITH PROGRAMMED INSTRUCTION
THE MAN WHO CAN MAKE A HARD THING EASY IS THE EDUCATOR. -- Emerson
THE MAN WHO MAKES THE EXPERIMENT DESERVEDLY CLAIMS THE HONOUR AND THE REWARD: Horace
IT IS BETTER TO UNDERSTAND LITTLE THAN TO MISUNDERSTAND A LOT. -- France
NO QUESTION IS EVER SETTLED UNTIL IT IS SETTLED RIGHT. -- Wilcox
MISSPENDING A MAN'S TIME IS A KIND OF SELF-HOMICIDE. -- Savile
NOTHING CAN BE DONE AT ONCE HASTILY AND PRUDENTLY. - Publius Syrus

THE LAST TWENTY YEARS has been an era of unequalled scientific achievement.

*The jet airplane has made this a smaller world, and, the world will shrink even more when the supersonic transport, cruising at Mach 2.5 to 3, travels from New York to Paris in just two hours.*

*Nuclear submarines and ships can travel for months without refueling. As yet, the full potential of nuclear power has not been realized.*

*With ten pulls of the dial you can make telephone contact with friends and business associates in all of the major cities of the United States, and, in the not-too-distant future, every telephone will be on 3D, Direct Distance Dialing.*

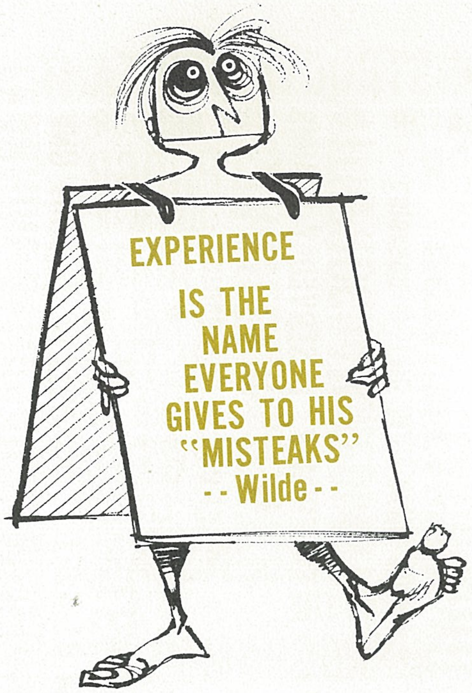
*The universe has been challenged with the penetration of outer space. A man on the moon is not too far in the future.*

*Automation necessitates a new breed of workers—men with educated judgement—men who can make a reasoned guess when insufficient facts are available.*

To cope with this expanding technology and the complex and challenging world of tomorrow, education patterns will have to keep pace. The traditional methods of teaching will have to be replaced with new techniques.

From the beginning of time, people have been trying to teach. Techniques ranged from skull-thumping, Chinese schoolboy repetition, donkey-carrot-stick method, apprenticeship system, medieval lecture system, on down to contemporary techniques like on-the-job training (apprenticeship system), Berlitz language courses (Chinese schoolboy technique), incentive classes (donkey-carrot method), visual education, simulated activities, and now, the latest method, *Programmed Instruction,* or PI.

The need for a new system of education to replace one that remained fundamentally unchanged for over a century was recognized more than ten years ago by Dr. B.F. Skinner of Harvard University. To move education into the 20th century and to keep pace with



our expanding technology, Dr. Skinner developed and perfected a method of instruction which we know today as Programmed Instruction. His method of instruction—Linear Programming—compelled the teacher to think as a student thinks—to get the student's point of view—and, through testing, to measure the effectiveness of this teaching method.

The Branching Method (or scrambled book program), developed by N.A. Crowder, has the same aims but it reaches them in a different manner. Both types of programming are discussed later in this article.

Early in 1961, GD/Convair got on the bandwagon to keep pace with new techniques in teaching and learning. At Convair, all techniques have been used, right up to date: "show-how," visual aids, demonstration of mechanical techniques, step-by-step books, Link trainers. And, since taking up Programmed Instruction, Convair has used it for training of their own personnel, for training of customer personnel, and for preparing training programs for other interested companies and for the military services.

Programmed Instruction, first of all, uses the Socratic approach of taking it one step at a time. The Socratic question is designed to make the student think about each step and to master it before going on with the total picture. Then PI calls on the donkey-carrot technique, because it is realized that the student learns more quickly and better when he gets a meaningful reward. These rewards for a question correctly answered can be a *very good, excellent, absolutely correct,* or just plain *right*. The answer, in many cases, will enlarge on the subject so that the student will be ready for more advanced material and more questions. The more right answers a student gets on his first attempt, the faster and harder he works to gain more, thereby learning faster and better.

If his answers are more often wrong than right, the student will feel that he is getting a variation of the Chinese schoolboy repetition technique, or some skull thumping. But then, every wrong answer gets another chance. His wrong answer will prompt a review of the information he should have attained up to this point. Then, with this reinforcement, it will take him back for that second chance—a chance to select another question.

There are two basic types of programs—Linear and Branching—and several variations of these two. Regardless of the type, the technique is basically the same, offering the following advantages.

Information is presented in short easy-to-digest installments, called "frames." Each succeeding frame is presented in a logical sequence, gradually developing the subject matter so that the student is hardly aware of the increase in difficulty of the topic.

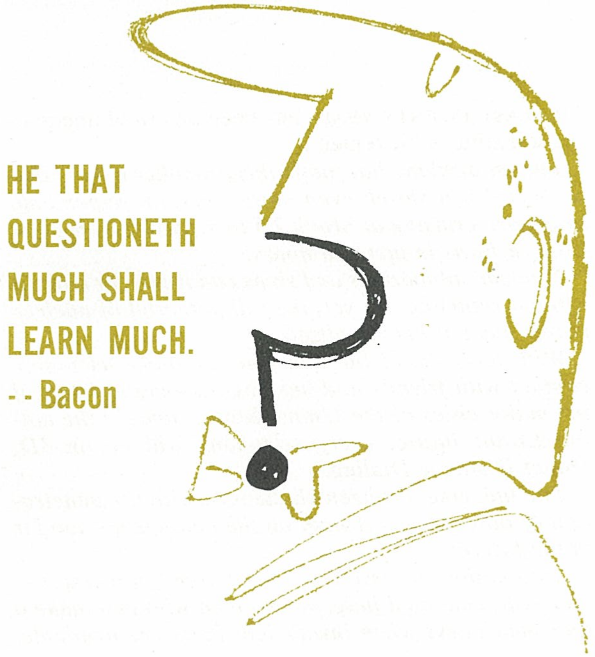
After each bit of information is digested, the student is required to answer a question regarding this information. The answer is immediately available and the student may compare his answer with the correct one.

Each student works individually, setting his own pace in respect to his aptitude and background.

The experienced student can pass over the basics of a course and forge ahead. In the traditional classroom course, the fast student is held back by the slow student, or, conversely, the slow student is required to keep pace with the fast student.

Only the essentials are taught.

The student is bolstered with information and then is encouraged to give relevant answers. This is especially important to the slow student who, by the end of the course, has acquired the same measure of knowledge as the bright student, thus averaging out the classroom level of the course.



Boredom of the traditional classroom with its drills and recitations is eliminated because the student is faced with a challenge each time he turns a page.

The student's path of progress is recorded.

Students score higher after taking programmed instruction courses than after finishing the traditional classroom type courses.

GD/Convair uses both the linear and branching methods of teaching, the type to be used depending on material coverage. But, before going into detail on these methods, a brief review of the various types of instruction may be in order.

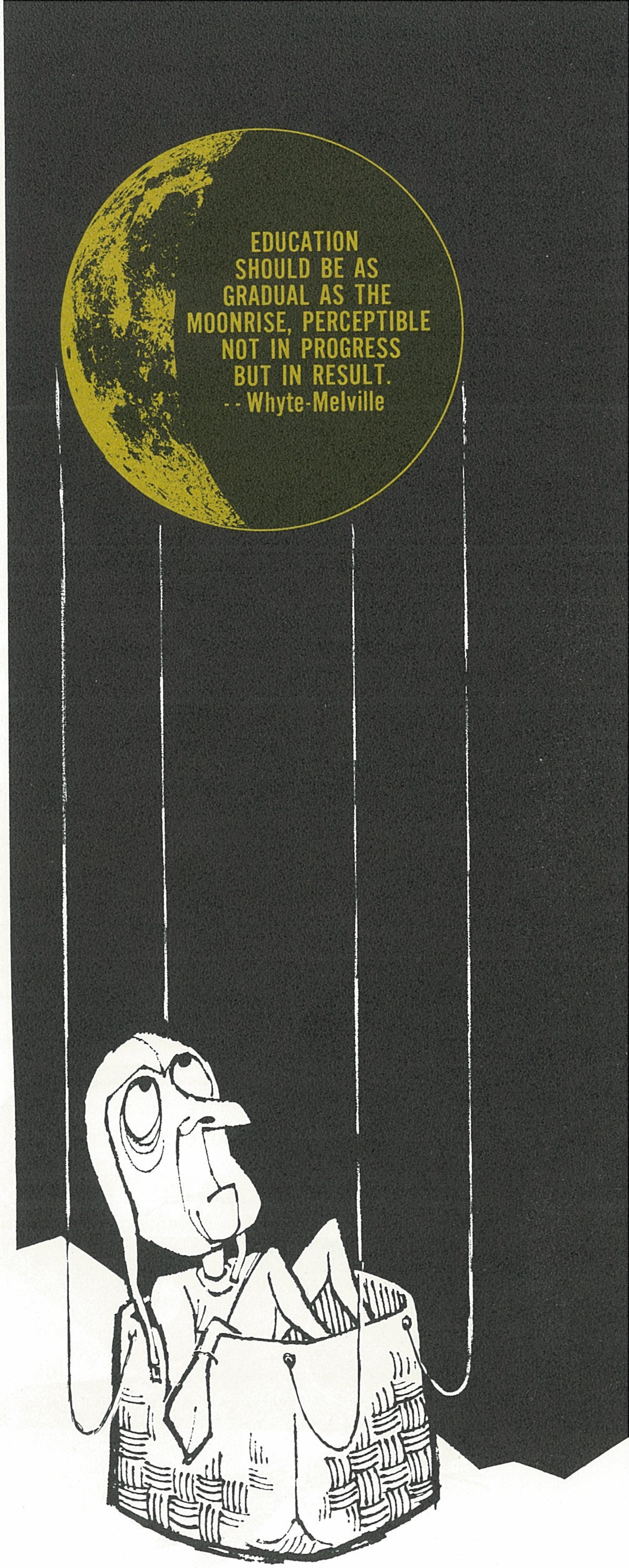
Many types of teaching machines are available today. They range from the simple mechanical training-aid type gadget to the complex computer-like electronic device. The major limitation of these machines today is in the limited amount of programmed material available for each type. Each different machine—and there are many—requires preparation of the program in a different manner—tape, film, cards, rolls, etc. This fact greatly limits the programmed material available to a machine owner.

Currently, GD/Convair uses only the programmed text which is simple, inexpensive, and easily adapted to any training program. The self-instructional text is a workable solution to many teaching/training problems in that a part-time instructor may be used to teach a number of students in a short period of time at moderate cost.

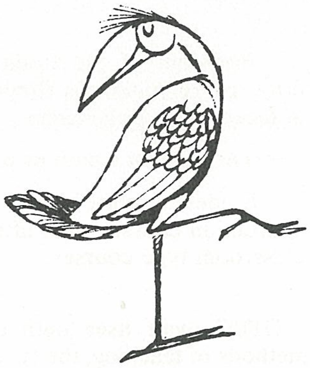
In the Linear method, programmed texts are read either horizontally or vertically. In the horizontal text, all the pages are read at one level from the front of the book to the back; then, the student goes back to the beginning and starts at the next level of the text and so on until the book is completed. The answer is always found on the following page. In the vertical text, the student reads each page from the top to the bottom, and from the front to the back. The answer is usually found on the same page, so a mask is required to conceal the answer until the student wants to check his response.

The Linear method presents instruction in a series of small steps, or frames, in a fixed logical sequence. All students work through the same sequence of frames which are prepared in such a manner that it is probable that the student will answer correctly each time. Proponents of this method believe that a wrong response may be learned and repeated in the future; therefore, the steps are kept short and simple to prevent a wrong response. Others feel that this oversimplified method does not present the challenge offered by the Branching method.

The Branching program (or scrambled book method), developed by N.A. Crowder, is a technique in which the student may be directed to go to several pages in a book—not necessarily in sequence—to get the information he needs. First, informative material is presented to the student; then, he is given a question and a choice of possible answers. The answer he may select directs him to another page in the book. If his choice is correct, he is told he is right (rewarded) and



EVERY STEP IS AN END, AND EVERY STEP IS A FRESH BEGINNING. --Horace

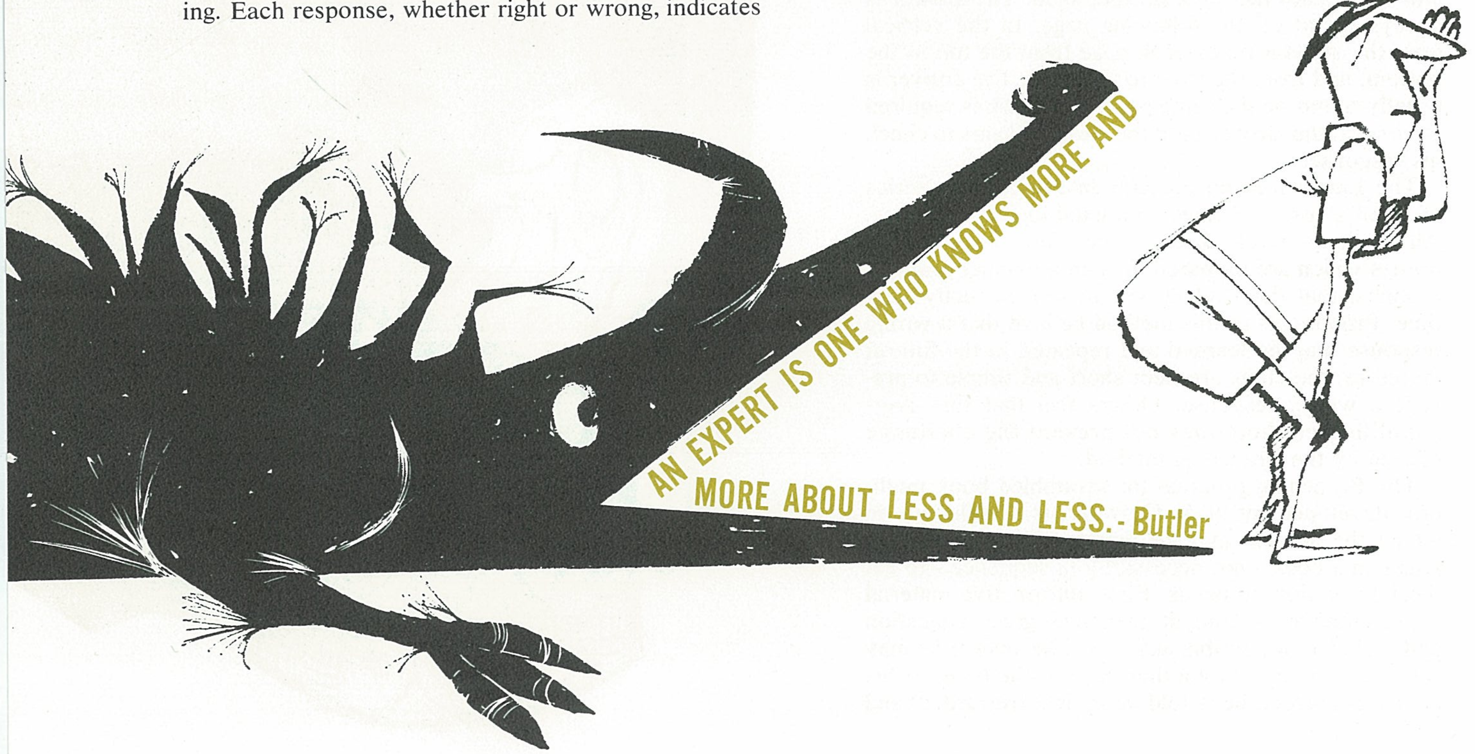


is then given additional information and another set of answers from which to choose.

If his choice is not right, or only partially acceptable, the student will be given additional information and then returned to the original page for a second chance, or he may be "branched" along a new path to give him additional background information. He will eventually wind up at the same point as the other students, but he will have been given more detailed instruction. Thus, a wrong answer does not necessarily hamper his learning; in fact, his knowledge of the subject is expanded.

The method in which the text is "scrambled" is important. Each answer is designed to evaluate the extent of the knowledge gained by the student up to that point, and to know where to send him next to gain additional knowledge or to correct a misunderstanding. Each response, whether right or wrong, indicates the thought processes of the student. While the bright student will finish earlier than the slow student, who is frequently branched to gain additional information, both students will cover the material necessary to bring them together down the parallel information course to the finish line.

Students have found that prior knowledge of a subject is unnecessary since the sequential presentation of each frame in the structure leads the student in simple stepwise fashion into more complex material as he progresses through the frames. This method has been compared by many educators to instruction with a private tutor, because its lucid sequential presentation teaches, tests, and rewards in a way that is personalized and infinitely more effective than the traditional method.



AN EXPERT IS ONE WHO KNOWS MORE AND MORE ABOUT LESS AND LESS. - Butler

Writing a program, or programming a course, requires more specific definition than does preparation of the traditional classroom instruction from text books. What will the trainee be required to know after he completes the course? Will the material and line of questioning route the student to the next logical step? Will the form of questioning and the programmed responses properly direct the student who needs additional reinforcement? Are the wrong answers designed to encourage rather than discourage the student? Does each response test the success of the latest communication to the student? Are the concepts clearly stated so that there are no misunderstandings or objections? Will each logical step guide the student through the course so that he will have a comprehensive understanding of the course at its conclusion?

These are some of the factors that must be considered in the successful programming of a course. A good comprehensive program requires a programmer with a good knowledge of the subject matter and a familiarity with all its phases. Some teaching experience is desirable but not required. At Convair—and this is true of many industrial firms—programmers are not required to be educators. It is more important that they know their subject than how to teach it. The programmed text, however, does not eliminate the teacher—it aids him, freeing him for individual instruction where required, and for concentration on problem areas. In industry, *part-time* instructors can be utilized, returning to full production when the course has been completed.

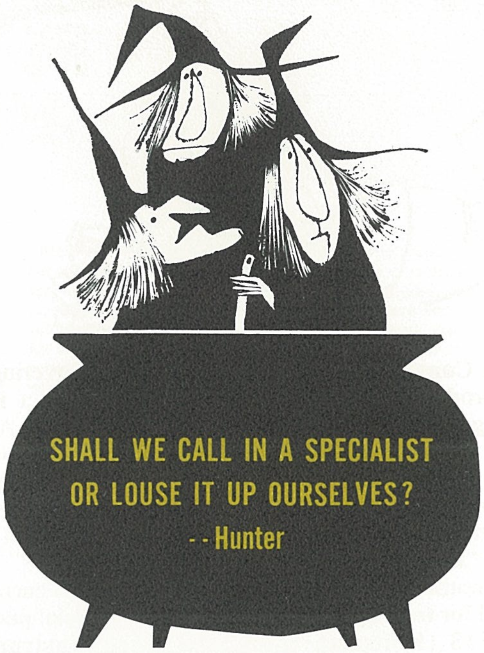
The student learns by doing, and he proceeds at his own pace, instead of trying to compete with a classroom of students of mixed knowledge and capability.

Testing a program to make it virtually error-proof is a "must." It is a tedious time-consuming process, but it can be very rewarding. The first rough draft of a program, or better still, a unit, or units, of the complete program, can be tried out on a co-worker to pick up any obscure meanings, omissions, technical mistakes, or unintelligible information. After rewriting and refining a program, it can and should be tried out again. This time, a typical student or students may be drafted for a trial run. The student's behavior is analyzed and the tenor of his response noted to govern sequence and pacing of the program and to determine the need and extent of rework required to further refine the program. The program is reviewed also by a subject matter specialist, and his comments noted and incorporated.

After several trial runs, the program is ready for its final trial run, usually by a class of students.

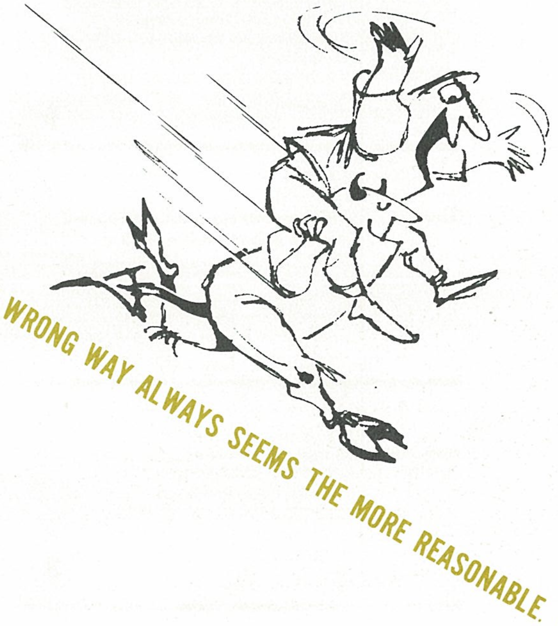
Without trial runs, no program is complete. It is the only means of demonstrating that a program course performs the function for which it is designed. At Convair, this trial run must result in a grade average of 90 per cent before the program is approved for publication and use.

At GD/Convair, a select group of technical writers was introduced to Programmed Instruction as early as 1961. Experts in the field of Programmed Instruction trained this initial group in the theory and techniques of programming. Some changes have been made in PI since then, and Convair has kept pace.

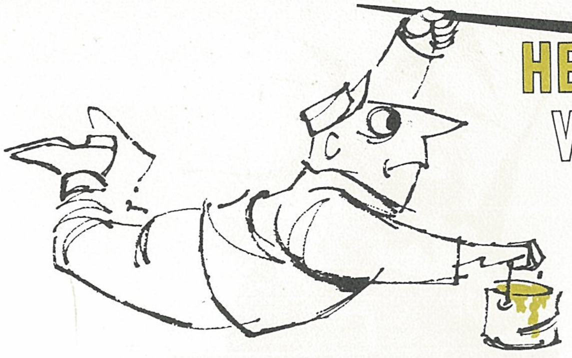


SHALL WE CALL IN A SPECIALIST OR LOUSE IT UP OURSELVES?
- - Hunter

Realizing that many teaching machines being offered were too expensive and too bulky to be used in the field, Convair developed their program courses in text book form for presenting technical and training material to employees. The success of in-house use of Programmed Instruction in the fields of Value Control and Quality Assurance led to inquiries from, and subsequent use by, other General Dynamics Divisions, the Military Services, and by a number of companies within the industry. The Value Control (Value Engineering) series of programmed texts have been used for more than a year by the General Dynamics organization. The classroom portion of the training program has been reduced by 50 per cent.



THE WRONG WAY ALWAYS SEEMS THE MORE REASONABLE. - - Moore



# HE HAS HALF THE DEED DONE, WHO HAS MADE A BEGINNING. . . HORACE

A Convair-prepared programmed text covering the "Aerodynamics of Sink Rate for Low-Aspect Ratio Wing Aircraft" was widely distributed by the ADC, and was enthusiastically received by Air Force pilots. The program was designed to instruct the pilot in the aerodynamic characteristics of Delta and swept-wing aircraft, and to alert him to the hazards he faces if he gets "behind the power curve."

Another course developed by Convair and currently used for training and retraining of commercial pilots is KIFIS (Kollsman Integrated Flight Instrument System).

A series of programs on Non-Destructive Testing were recently released to the industry and have met with high praise. In one phase of this program, eight students were trained for certification in Magnetic Particle Inspection. Time to train was only three days as compared with five days for conventional instruction; and, it was possible to present the material in greater detail. It naturally followed that the tests, too, would be more detailed and extensive. Nevertheless, the grade average was 93 per cent. And, what was the students' reactions to this type training? *Enthusiastic!*

These programs are available to anyone interested in the education, training, and certification of their personnel in the various technical fields.

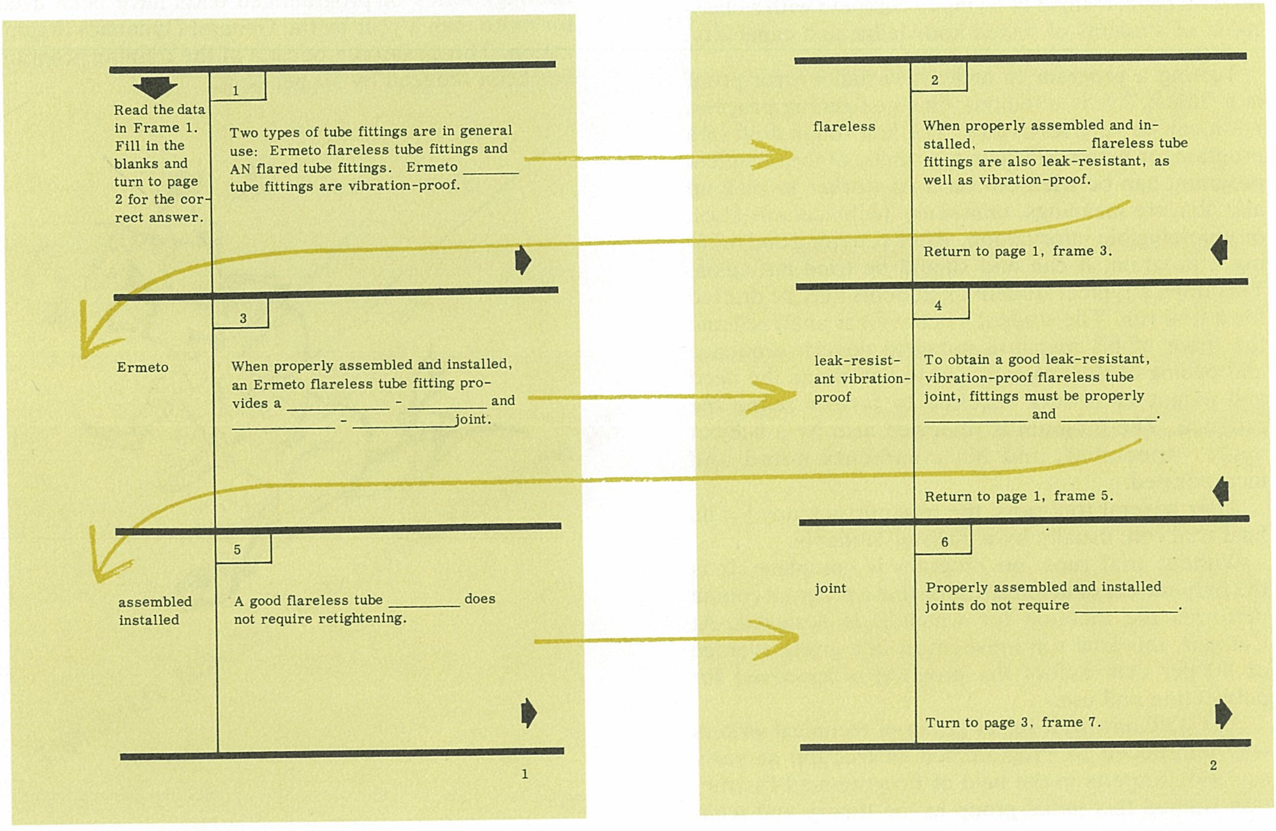
Other programs currently available and those to be released in the future are listed on the back cover.

Convair's capabilities in the field of Programmed Instruction have been tested and proved. The services of the PI team are available to apply the programming approach to any subject material that can feasibly be programmed.

All inquiries should be directed to H.R. Kennedy, Chief of Technical Publications, General Dynamics-Convair, P.O. Box 1950, San Diego, California, 92112.

Now, are you ready to try your hand at Programmed Instruction? You can start with the Linear method shown below. Good Luck!

## Linear Method



Read the data in Frame 1. Fill in the blanks and turn to page 2 for the correct answer.

1

Two types of tube fittings are in general use: Ermeto flareless tube fittings and AN flared tube fittings. Ermeto _______ tube fittings are vibration-proof.

Ermeto

3

When properly assembled and installed, an Ermeto flareless tube fitting provides a _________ - _________ and _________ - _________ joint.

assembled installed

5

A good flareless tube _________ does not require retightening.

1

flareless

2

When properly assembled and installed, _____________ flareless tube fittings are also leak-resistant, as well as vibration-proof.

Return to page 1, frame 3.

leak-resistant vibration-proof

4

To obtain a good leak-resistant, vibration-proof flareless tube joint, fittings must be properly _____________ and _____________.

Return to page 1, frame 5.

joint

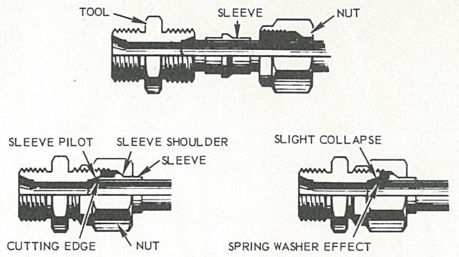
6

Properly assembled and installed joints do not require _____________.

Turn to page 3, frame 7.

2

# Branch Method



A tight MS fitting is not necessarily a "dry" fitting, nor is a slightly loose fitting necessarily a "wet" joint. The component parts of the MS flareless tube fitting and assembly sequence are illustrated. Tighten the nut until the cutting edge of sleeve grips the tube. This is determined by turning tube slowly but firmly with fingers, while tightening nut with wrench. A point will be reached when tube can no longer be turned with fingers. This increased resistance indicates that sleeve is in full contact with fitting. From this point, turn nut a maximum of 1-1/6 turns; excessive tightening will result in leakage and/or permanent damage to sleeve and tube. If joint leaks after a period of service — (select one of the following answers.

1. Disconnect fitting, cut off tube, and again perform preset operation. See page 3.
2. Tighten nut to again force sleeve into tube. See page 8.
3. Back off nut and check tube for proper alignment. See page 6.

1

---

I believe it would be wise to take some interim steps here before going back to the tube cutting and presetting operation. The leak may be the result of misalignment or of foreign matter on the tube or fittings. Back off nut, and check that tube is properly aligned; check also for evidence of any damaged tube or fittings, and for presence of foreign matter. If assembly passes check, relubricate, reinstall tube, and repeat tightening procedure. Now, if assembly does not pass check, you can replace tube, or cut off damaged section, if feasible, and perform preset operation.

We recommend going back to page 1 for another selection.

3

---

You are absolutely right. Do not under any circumstances tighten a leaky joint; otherwise damage to the tube with continued leakage will result. Back off the nut until finger loose; check tube for proper alignment and then retighten. Do not overtighten. If leak persists, disconnect fitting and check for foreign matter or nicked tube or fittings. If assembly parts pass check, relubricate, reinstall tube, and repeat tightening procedure. If assembly does not pass check replace tube or cut off tube, if feasible, and perform preset operation.

Now, are you ready for your next lesson?

When assembling and installing the preset flareless tube in proper position in the system, align tube against shoulder of connector fitting. Run approximately three threads of nut onto fitting; if they cannot be engaged by fingertightening, check tube alignment, sleeve preset, and for freedom from burrs and particles. If tube and connector are not properly aligned:

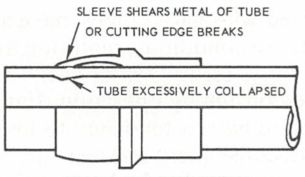
1. Back off nut and start over. See page 11.
2. Start nut with wrench. See page 9.
3. Check tube alignment, sleeve, preset, and for freedom from burrs and particles. See page 10.

6

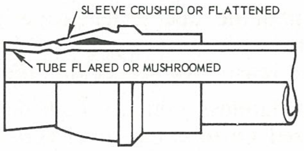
---

This is true of AN flared tube fittings and we recommend tightening, but, please, not MS (ER) fittings. Remember, a wet flareless joint does not necessarily mean the fitting is loose. If this fitting is tightened (after its initial tightening), the greater-than-normal tightening force on the nut will shear the metal near the end of the tube, or the cutting edge of the sleeve may break, requiring replacement. A glance at the sketch will show you what happens when a flareless tube fitting is overtightened.

Return to page 1 and select another answer.



FITTING OVERTIGHTENED

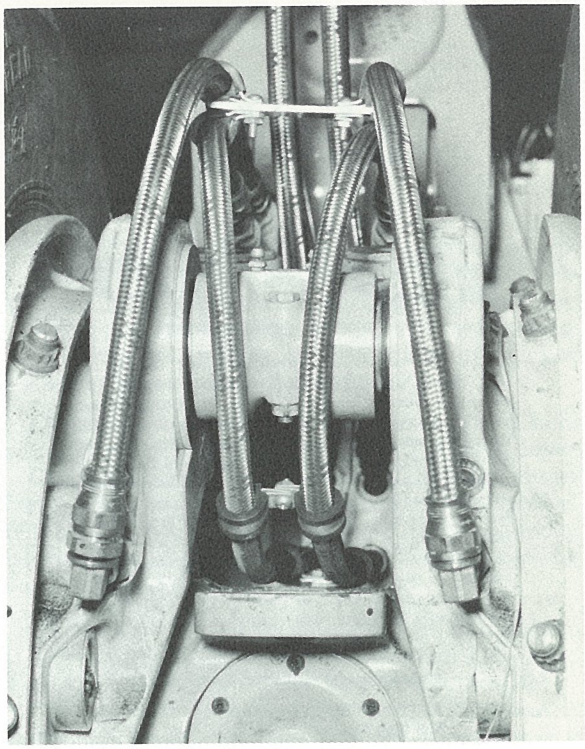


EXTREME CASE OF OVERTIGHTENING

8

# MS(ER)

## Flareless Tube Fittings



STANDARD CONNECTORS used in tubing applications of all Convair jet airliners, and in some Convair 340/440 type aircraft, are MS(ER) flareless tube fittings, or Ermeto fittings as they are sometimes called.

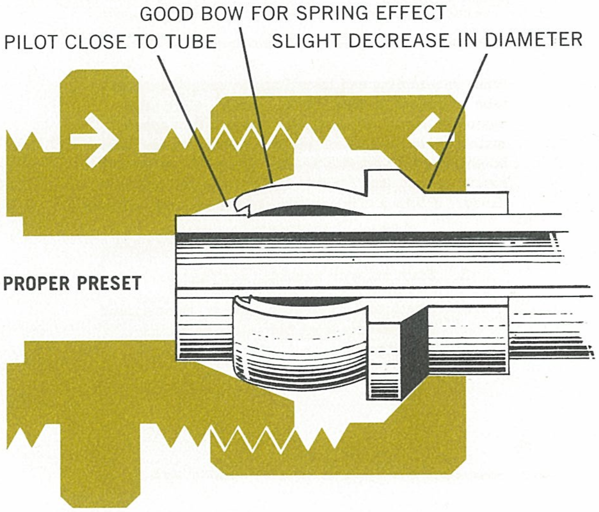
At the beginning of the Convair 340 program, flareless fittings were designated with ER numbers and these numbers bore the same numerical designation as corresponding shapes for the AN fittings, except that the number was prefixed by ER instead of AN. Today, these fittings, with a few exceptions carry MS numbers.

MS(ER) fittings are designed to withstand the pressure loads of the 3000-psi hydraulic system; they provide a joint that is resistant to vibrations associated with jet aircraft; to vibrations encountered in severe turbulence; and to jolts associated with hard landings. AN fittings, used with flared tubes, have a tendency to loosen under these conditions, requiring frequent tightening, or, possibly, safety wiring of the nut, which in itself is a time-consuming operation. Fatigue-induced loads on the flare have a tendency to loosen the connector nut with consequent leakage, and a need for retightening. In many cases, the loads described caused the flare to crack, resulting in leakage and the necessity for replacement of the tube. When properly assembled, MS(ER) joints are less susceptible to fatigue cracks and there is no reason for rechecking the torque.

In MS(ER) flareless joints, a considerable weight saving is realized. On tube sizes over $^3/_8$ inch, aluminum nuts are used, except in high pressure lines and in the pod and pylon areas. In these applications, steel nuts are required.

Additional savings are effected in the simplicity of tube end preparation. In the flareless connection, it is necessary only to cut and smooth the tube end; whereas, the flared fittings require special tools and techniques for the flaring process. The mechanical properties of the various metals necessitate additional techniques and shop practices for the tube flaring operation. Because flare forming and resultant thinning operations are eliminated with the flareless connection, lighter, yet stronger, tube materials may be used.

Unlike flared tube fittings, MS fittings may be disassembled and reassembled a number of times without



affecting sealing qualities; however, these operations require a certain amount of care, especially in the application of torque upon reassembly.

When tightening MS fittings, maintenance personnel are cautioned to ease up on the torquing operation. Only a moderate amount of torque is required. When properly assembled, preset, and installed, MS fittings require no retightening.

Overtorquing a flareless fitting can result in a leaky fitting and/or a damaged tube end, or misalignment and stresses on connections. Unlike AN fittings, a tight MS(ER) fitting is not necessarily a "dry" fitting, nor is a slightly loose fitting necessarily a "wet" joint.

A sleeve that is undertightened (no arching) is also undesirable, since it will easily blow off under pressure or will leak.

Figure 1 shows a flareless joint that is properly tightened and those that are over- and undertightened.

Disconnecting MS fittings is somewhat more difficult than disassembling AN tube joints. The MS tube end, engaging the fitting, must be round and straight (without a bend) for twice the length of the sleeve nut, and the end of the tube must be bottomed on the flareless connector for proper tube end support. This means that the tube must be withdrawn from the connector for a distance of twice the length as that required to uncouple an AN fitting. To obtain springback for withdrawing the tube, at least one bend is required in the tube. To overcome this in areas where straight runs are required, an Ermeto union is installed between the connecting points. The assembly may be displaced sufficiently at the union, after uncoupling both ends of the tube, to permit removal. The additional time required to disconnect an MS fitting far outweighs the leakage problems encountered with AN fitting connections.

Basically, a flareless joint is comprised of a steel sleeve, and a nut which can be of aluminum or stainless steel. The first step towards obtaining a leakproof joint is on initial assembly, or "preset" operation. During this operation, the nut is tightened just enough to force the sleeve forward on the tube so that it rests against the shoulder of the preset tool, and the nut contacts the bevel of the sleeve. As the nut and sleeve move together, the cutting edge on the sleeve contracts, forcing the cutting edge of the sleeve to shear a groove in the outer surface of the tube (see figure 2).

As the nut is screwed onto the tube body, it presses on the bevel of the sleeve; with this action, the cutting edge of the sleeve "bites" into the tube, and the area aft of the bevel clamps tightly to the tube. Resistance to vibration is concentrated mainly aft of the bevel area rather than at the sleeve cut.

When fully tightened, the case-hardened steel sleeve, acting as a spring, will bow, or arch, slightly at the midsection. This spring action maintains a constant tension between the body and the nut to prevent the nut from loosening when vibration is encountered. When disassembled, some of the bow in the sleeve will disappear because of the springback action of the sleeve; this spring-back action will not affect the strength or sealing qualities of the joint, because the bow is restored when the fitting is reassembled and tightened.

Following is the correct step-by-step method for assembling flareless tube fittings.

Cut the tube end reasonably square, and burr inside and outside of tube end so that it is smooth. A hacksaw is recommended for cutting stainless steel since it does not work-harden stainless steel as much as does a tube cutter.

Be sure all parts of the assembly—sleeve, nut, connector, seat, and tube—are clean and free from burrs and foreign particles, which could interfere with a good seal.

Lubricate the nut, outer surface of sleeve, and the threads and body of the preset tool with a lubricant

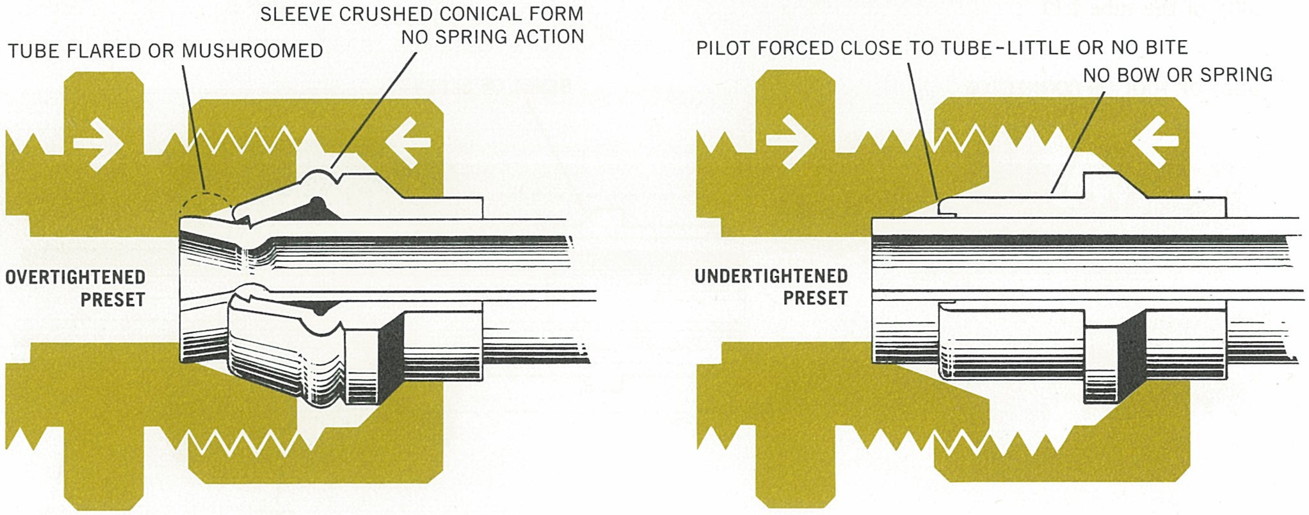

SLEEVE CRUSHED CONICAL FORM
NO SPRING ACTION
TUBE FLARED OR MUSHROOMED
OVERTIGHTENED
PRESET
PILOT FORCED CLOSE TO TUBE-LITTLE OR NO BITE
NO BOW OR SPRING
UNDERTIGHTENED
PRESET

*Figure 1.*

that is compatible with the system. Use lubricant sparingly. *Do not use lubricant on oxygen system fittings.*

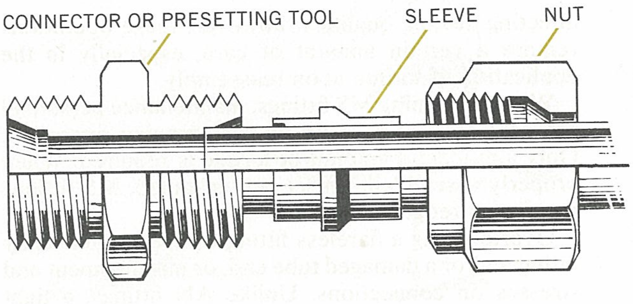
First, slide nut onto the tube, being sure threaded portion faces end of tube.

Then, slip sleeve over tube, being sure beveled shoulder faces the nut (see figure 3). Reversal will prevent pressure-tight sealing of the joint and will cause the tube to slip out of the fitting when pressure is applied.

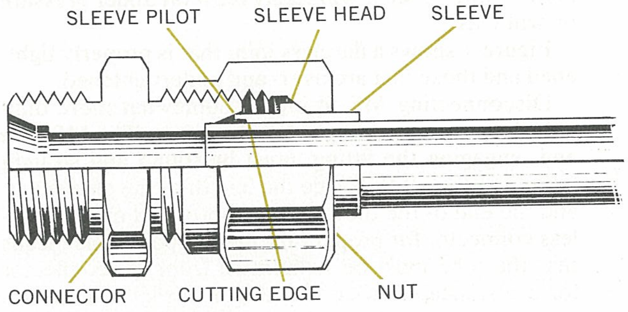
Insert assembled tube end into connector or presetting tool. It is important that the tube be inserted so that the tube end will be firmly bottomed against the connector or presetting tool seat. A gap at this point will result in an unsatisfactory sleeve cut because of the tube moving with the sleeve when the sleeve nut is tightened (see figure 2). Be sure nut bears on sleeve shoulder. Misalignment may strip threads and cause concentration of stresses at the wrong places.

If the nut moves freely on the fitting, slowly turn the tube with the fingers and thumb while tightening the nut with a wrench. As the nut is tightened, a point will be reached where the tube can no longer be turned by hand. This increased resistance indicates that the sleeve is in full contact with the fitting. Hold connector firmly during tightening to prevent rotation.

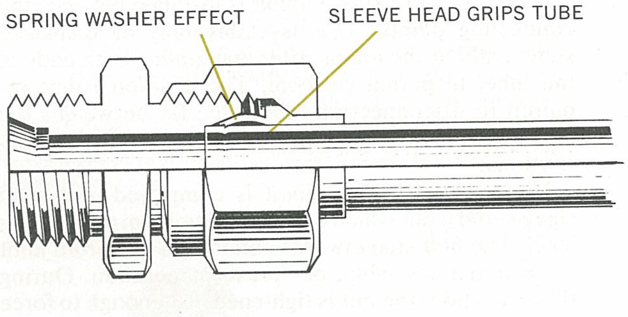
From this point, where a sharp rise in torque is noted, turn the nut a maximum of 1$\frac{1}{6}$ turns (one full turn plus one flat on the nut). Table I gives the recommended number of turns for the combination of tube sizes, materials, and wall thicknesses. These tightening requirements should not be exceeded. Excessive tightening will result in leakage and/or permanent damage to the sleeve and tube. Aluminum 5052-0 tubing requires only $\frac{5}{6}$ turn to 1 turn to obtain proper "bite" of the sleeve on tubing. It is recommended that a mandrel be used for the preset operation to preclude collapsing of the tube. The mandrel should be within .005 of the tube I.D.



**COMPONENT PARTS**



**AS THEY GO TOGETHER**



**ASSEMBLED CONNECTION**

*Figure 2.*

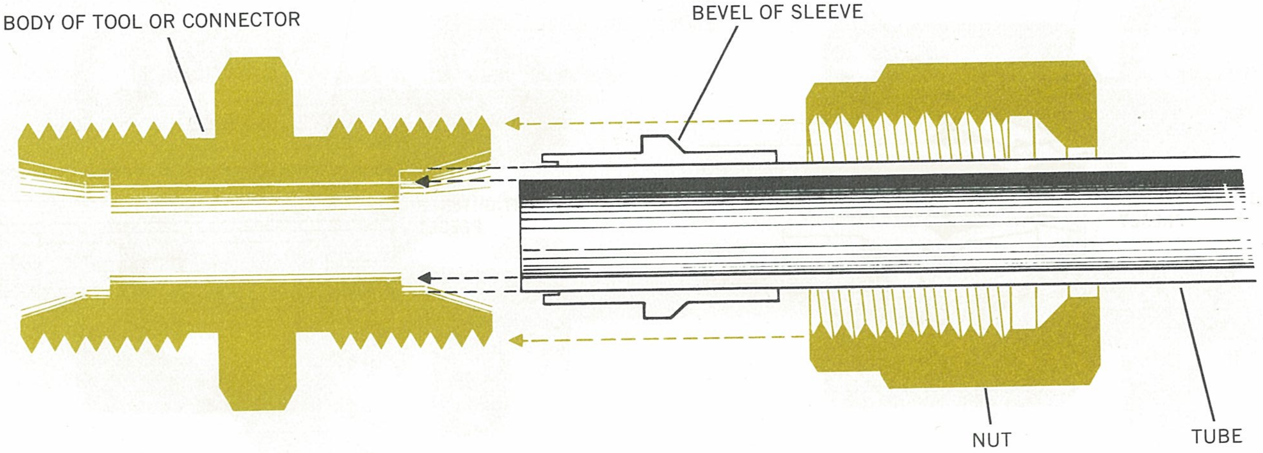


*Figure 3.*

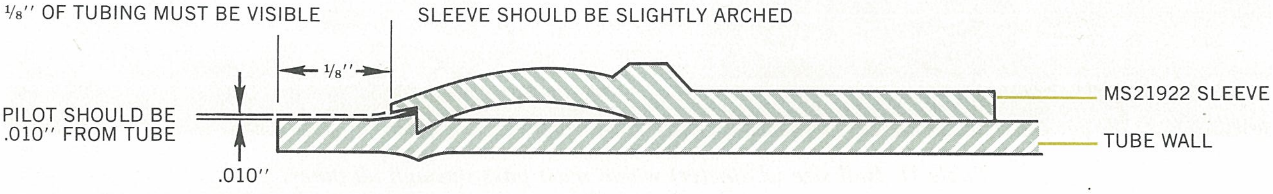
**Case Hardened and Stainless Steel Tubing**

| TUBE O.D. | .016 | .020 | .028 | .035 | .042 | .049 | .058 | .065 | .072 | .083 | .095 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/16 | 1-1/6 | 1-1/6 | 1-1/6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | – |
| 1/4 | – | 1-1/6 | 1-1/6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | – |
| 5/16 | – | 1-1/6 | 1-1/6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | – |
| 3/8 | – | – | 1-1/6 | 1 | 1 | 5/6 | 5/6 | 5/6 | 5/6 | 5/6 | – |
| 1/2 | – | – | 1-1/6 | 1-1/6 | 1 | 1 | 5/6 | 5/6 | 5/6 | 5/6 | 5/6 |
| 5/8 | – | – | 1-1/6 | 1-1/6 | 1-1/6 | 1 | 2/3 | 2/3 | 2/3 | 2/3 | 5/6 |
| 3/4 | – | – | – | 1-1/6 | 1-1/6 | 1 | 2/3 | 2/3 | 2/3 | 2/3 | 2/3 |
| 1 | – | – | – | – | 1-1/6 | 1-1/6 | 1 | 2/3 | 2/3 | 2/3 | 5/6 |
| 1-1/4 | – | – | – | – | 1-1/6 | 1-1/6 | 1 | 2/3 | 2/3 | 2/3 | 2/3 |
| 1-1/2 | – | – | – | – | – | 1-1/6 | 1-1/6 | 1 | 2/3 | 2/3 | 5/6 |
| 2 | – | – | – | – | – | – | 1-1/6 | 1-1/6 | 2/3 | 2/3 | 5/6 |

**Aluminum Alloy 6061**

| TUBE O.D. | .016 | .020 | .028 | .035 | .042 | .049 | .058 | .065 | .072 | .083 | .095 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/16 | 5/6 | 1 | 1-1/6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | – |
| 1/4 | 1 | 1 | 1-1/6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | – |
| 5/16 | – | 1-1/6 | 1-1/6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | – |
| 3/8 | – | 1-1/6 | 1-1/6 | 1-1/6 | 1-1/6 | 1 | 1 | 5/6 | 5/6 | 5/6 | – |
| 1/2 | – | 1-1/6 | 1-1/6 | 1-1/6 | 1-1/6 | 1 | 1 | 5/6 | 5/6 | 5/6 | 1 |
| 5/8 | – | – | 1-1/6 | 1-1/6 | 1-1/6 | 1-1/6 | 1 | 1 | 5/6 | 5/6 | 1 |
| 3/4 | – | – | 1 | 1 | 1-1/6 | 1-1/6 | 1 | 1 | 5/6 | 5/6 | 5/6 |
| 1 | – | – | 1 | 1 | 1-1/6 | 1-1/6 | 1-1/6 | 1 | 1 | 5/6 | 5/6 |
| 1-1/4 | – | – | 1 | 1 | 1-1/6 | 1-1/6 | 1-1/6 | 1 | 1 | 5/6 | 1 |
| 1-1/2 | – | – | 1 | – | – | 1-1/6 | 1-1/6 | 1-1/6 | 1 | 1 | 1 |
| 2 | – | – | – | – | – | – | 1-1/6 | 1-1/6 | 1 | 1 | 1 |

*Table I. Tube wall thickness and number of turns for presetting without mandrels.*



1/8'' OF TUBING MUST BE VISIBLE
SLEEVE SHOULD BE SLIGHTLY ARCHED
1/8''
PILOT SHOULD BE .010'' FROM TUBE
.010''
MS21922 SLEEVE
TUBE WALL

*Figure 4.*

Remove tube from presetting tool and ascertain that at least 1/8 inch of the tubing is visible in front of the sleeve pilot, and that the cutting edge of the sleeve "bites" into the tube so that the sleeve pilot is approximately .010 inch from tube O.D. (see figure 4). There may be a slight collapse of the tubing wall under the sleeve cutting edge – especially in softer materials – but this is normal. Unless the sleeve is firmly "embedded" in the tube, applied pressure could sever the connection. The sleeve will be slightly sprung and arched after preset operation, and it may be possible to rotate the sleeve on the tube; however, intentional rotation is not recommended. It should not be possible to move the sleeve forward and backward on the tube more than 1/64 inch. Table II gives the minimum tube I.D. (ball passage limits) allowable after presetting.

| **TUBE O.D.** **(Nominal)** **FOR I.D. CHECK** | **WALL THICKNESS** (Nominal) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **.012** | **.016** | **.022** | **.028** | **.035** | **.042** | **.049** | **.058** | **.065** | **.083** | **.095** |
| **1/8** | 5/64 | – | – | – | – | – | – | – | – | – | – |
| **3/16** | – | 1/8 | 1/8 | 7/64 | 3/32 | 5/64 | 1/16 | – | – | – | – |
| **1/4** | – | – | 3/16 | 11/64 | 5/32 | 9/64 | 1/8 | 7/64 | 3/32 | – | – |
| **5/16** | – | – | 1/4 | 15/64 | 7/32 | 13/64 | 3/16 | 11/64 | 5/32 | 1/8 | 3/32 |
| **3/8** | – | – | 5/16 | 19/64 | 9/32 | 17/64 | 1/4 | 15/64 | 7/32 | 3/16 | 5/32 |
| **7/16** | – | – | 3/8 | 23/64 | 11/32 | 21/64 | 5/16 | 19/64 | 9/32 | 1/4 | 7/32 |
| **1/2** | – | – | 7/16 | 27/64 | 13/32 | 25/64 | 3/8 | 23/64 | 11/32 | 5/16 | 9/32 |
| **9/16** | – | – | 1/2 | 31/64 | 15/32 | 29/64 | 7/16 | 27/64 | 13/32 | 3/8 | 11/32 |
| **5/8** | – | – | 9/16 | 35/64 | 17/32 | 33/64 | 1/2 | 31/64 | 15/32 | 7/16 | 13/32 |
| **11/16** | – | – | 5/8 | 39/64 | 19/32 | 37/64 | 9/16 | 35/64 | 17/32 | 1/2 | 15/32 |
| **3/4** | – | – | 11/16 | 43/64 | 21/32 | 41/64 | 5/8 | 39/64 | 19/32 | 9/16 | 17/32 |
| **7/8** | – | – | 13/16 | 51/64 | 25/32 | 49/64 | 3/4 | 47/64 | 23/32 | 11/16 | 21/32 |
| **1** | – | – | 15/16 | 59/64 | 29/32 | 57/64 | 7/8 | 55/64 | 27/32 | 51/64 | 25/32 |
| **1-1/8** | – | – | 1-1/16 | 1-3/64 | 1-1/32 | 1-1/64 | 1 | 63/64 | 31/32 | 15/16 | 29/32 |
| **1-1/4** | – | – | 1-3/16 | 1-11/64 | 1-5/32 | 1-9/64 | 1-1/8 | 1-7/64 | 1-3/32 | 1-1/16 | 1-1/32 |
| **1-3/8** | – | – | 1-5/16 | 1-19/64 | 1-9/32 | 1-17/64 | 1-1/4 | 1-15/64 | 1-7/32 | 1-3/16 | 1-5/32 |
| **1-1/2** | – | – | 1-7/16 | 1-27/64 | 1-13/32 | 1-25/64 | 1-3/8 | 1-23/64 | 1-11/32 | 1-5/16 | 1-9/32 |

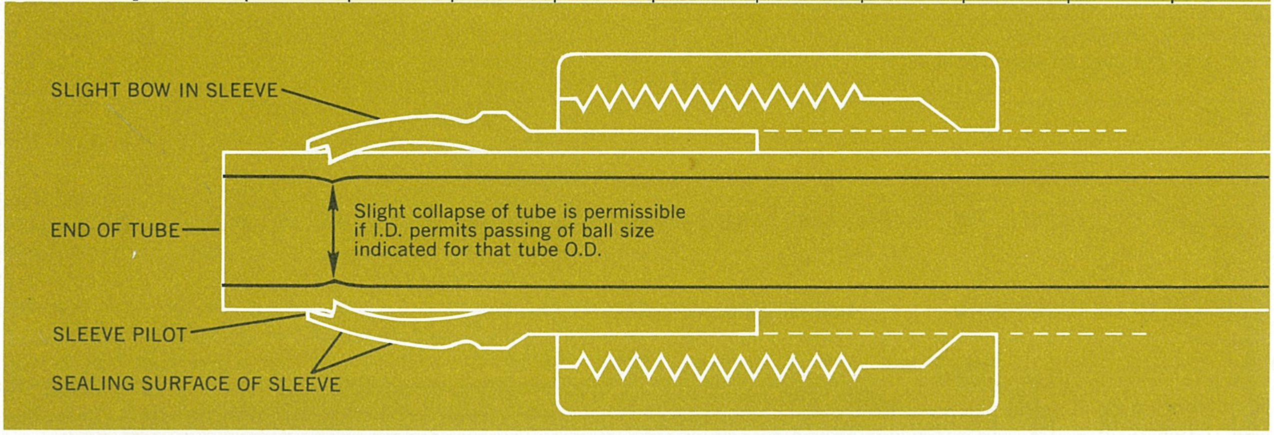

SLIGHT BOW IN SLEEVE
END OF TUBE
Slight collapse of tube is permissible if I.D. permits passing of ball size indicated for that tube O.D.
SLEEVE PILOT
SEALING SURFACE OF SLEEVE

*Table II. Ball size (diameter) which must pass through all tubes.*

When assembling and installing the preset tube in the proper position in the system, align the tube against the shoulder of the connector fitting.

Run approximately three threads of the nut onto the fitting to ensure that alignment is correct and threads are free. If first three threads cannot be engaged by fingertightening, do not proceed further until corrective action has been taken. Check tube alignment, sleeve preset, and for freedom from burrs and particles. Do not attempt to correct misalignment by starting nut with wrench.

The AN-to-ER connector fitting is notched for easy identification (figure 5). This notch indicates to the mechanic that there is an AN fitting on one end and a flareless fitting on the other, so that the flareless end will not be overtightened.

Since MS fittings have standard threads—the same as AN flared fittings—they can be mated with existing

AN internal threads in valves, pumps, and other accessories.

Again lubricate with suitable fluid, and tighten the nut until a decided increase in resistance to turning of the nut is encountered, indicating that the tubing, sleeve, and connector are in contact. Then apply 1/6 turn (one flat on nut) from this point. Turning two flats on the nut, or 1/3 turn, is the absolute maximum permitted.

If the fitting leaks, *do not* under any circumstances tighten the nut; otherwise, damage to the tube with continued leakage will result. If a joint is leaking, back off the nut until finger loose; check tube for proper alignment and then retighten. *Do not overtighten.* Overtorquing the nut forces the sleeve deeper into the tube with possible shearing of the tube end; breaking of the sleeve cutting edge; or collapsing of the tube, decreasing the allowable I.D. In any event, a preset operation becomes necessary. If a leak persists, disconnect fitting and check for any condition that could result in poor contact of the nut with the sleeve—foreign matter on the threads, a nicked tube or fitting. Check inside diameter of tube at sleeve area. I.D. of tube should be sufficient to pass the ball test. If assembly passes check, relubricate, reinstall tube, and repeat tightening procedure. *Do not exceed the 1/6 to 1/3 turn on the nut when retightening the fitting.* Permanent damage to the sleeve and tube will result.

If assembly does not pass the check, replace tube or cut off tube, if feasible, and perform preset operation.

MS and vendor part numbers are the same for both steel and aluminum alloy fittings except that the letter "D" in the tubing size indicates aluminum alloy; a "C" indicates a fitting of stainless steel; no letter indicates case-hardened carbon steel. For example:

| Stainless Steel | Alum Alloy | *CH Steel* |
|---|---|---|
| MS21923-2C | MS21923D2 | MS21923-2 |

These numbers are formed as follows:

ER 815 4D
MS 21912 D4

Tube size in 16ths inch
Fitting material D indicates aluminum alloy
Designation of tube fitting
Military Standard (MS) or vendor (ER)

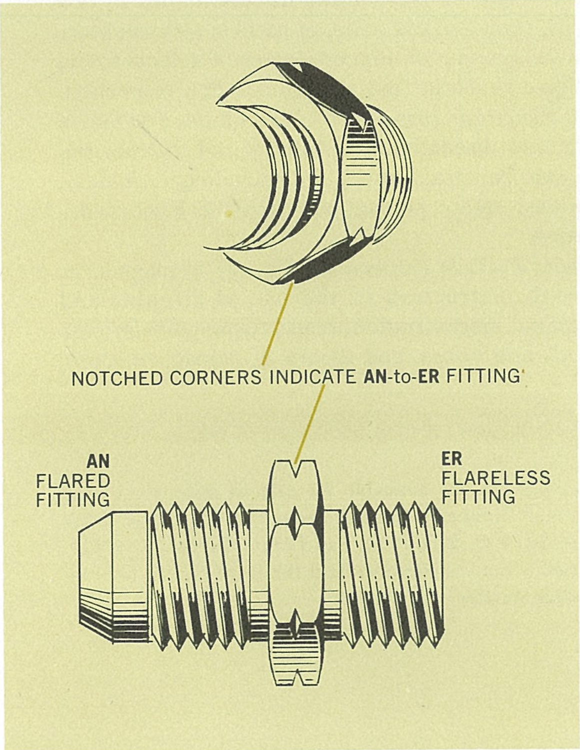


*Figure 5.*

Following is a quick reference list for flareless tube fittings with the equivalent ER and/or MS numbers.

| ER P/N | MS P/N | FITTING |
|---|---|---|
| 783 | 21910 | Elbow, 90-degree |
| 784 | 21911 | Tee, with Internal Thread on Run |
| 804 | 21912 | Tee, with Bulkhead on Run |
| 806 | 21913 | Plug |
| 815 | 21902 | Union |
| 816 | 21923 | Adapter, Flareless-to-AN Flared Tube Blkhd |
| 818 | 21921 | Nut, Short, for Use with MS21922 Sleeve |
| 819 | 21922 | Sleeve, Long, for Use with MS21921 Nut |
| 821 | 21904 | Elbow, 90-Degree |
| 822 | | Elbow, 90-Degree |
| 823 | | Elbow, 45-Degree |
| 824 | 21905 | Tee |
| 826 | | Tee, Pipe Thread on Side |
| 827 | 21906 | Cross |
| 832 | 21903 | Union, Bulkhead |
| 833 | 21908 | Elbow, 90-Degree Bulkhead |
| 834 | 21909 | Tee, Bulkhead Port on Side |
| 837 | 21907 | Elbow, 45-Degree Bulkhead |
| 894 | 21915 | Bushing, Flareless-to-Screwthread Adapter |
| 919 | 21916 | Union, Reducer |
| 1804 | 21914 | Cap, Pressure Seal |
| 1833 | | Elbow, Swivel Nut on one End |
| 1834 | | Tee, Swivel Nut |
| | 21937 | Nut, Cluster Fitting |
| | 21938 | Bolt, Cluster Fitting |
| | 21942 | Connector, Cluster Fitting |
| | 21949 | Bolt, Cluster Fitting |

# Programmed Instruction Courses

*developed by General Dynamics/Convair*

## For the Military

Aerodynamics of Sink Rate – High Performance Aircraft
Ejection Versus Forced Landing
Jet Engine Operation – High Altitude
Pitch-Up – Jet Interceptor Aircraft

## For Industry*

Value Engineering (Value Control)

A series of five programmed texts which concentrate on teaching decision-making employees in the use of an organized approach to eliminate unnecessary costs from products and services.

Quality Assurance

*Orientation* – A survey of principles and techniques covering, in broad terms, the entire Quality Assurance Program.

*Traceability* – An introduction to industrial traceability, stressing the responsibilities of the individual and the importance of records and identification.

*Control of Nonconforming Materials* – The presentation of methods used for control and disposition, including the roles of foreman and inspector.

Nondestructive Testing

*Introduction* – An introduction to basic metallurgy and the origin of defects and discontinuities in raw material, semi-finished parts, or parts in service; practice in recognition of common types of defects found with liquid penetrant and magnetic particle inspection.

** *Liquid Penetrant Inspection* – Method used to locate defects and discontinuities; history and theories behind liquid penetrant inspection, including usefulness, limitations, safety precautions, and the basic materials used.

** *Magnetic Particle Inspection* – Theory of magnetization with instruction in the use of circular and longitudinal magnetization, magnetizing currents, use of prods and yokes, and theory of demagnetization.

---

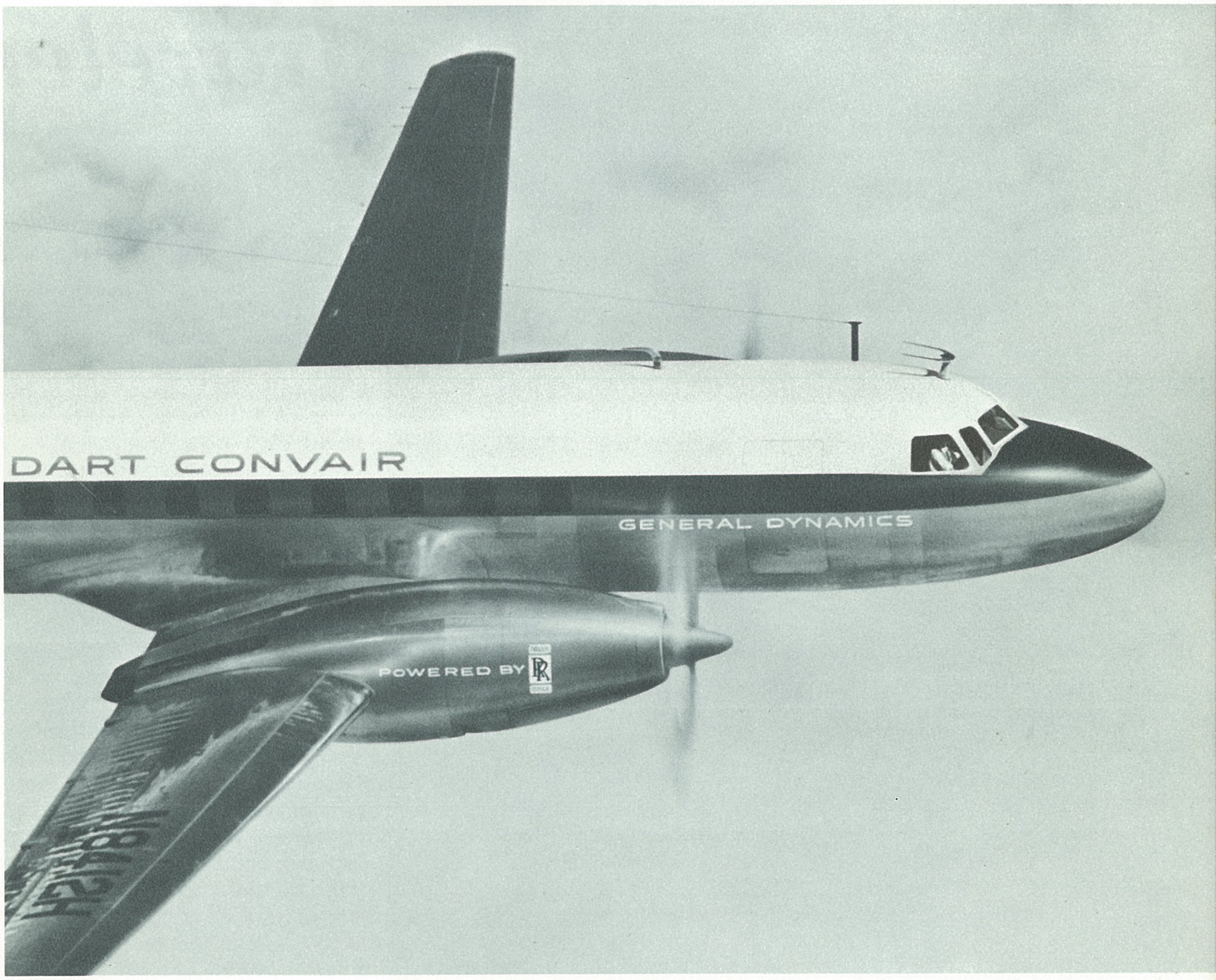
* These programs are available for sale to industry. Please contact H. R. Kennedy, Chief of Technical Publications, Mail Zone 16-10, P.O. Box 1950, San Diego, California, 92112.

** This book is not complete without the Introduction to Nondestructive Testing.

GENERAL DYNAMICS | CONVAIR

VOLUME XVI NUMBER 2 JULY|AUGUST 1964

# Convair Traveler



## In This Issue: The DART-Convair

VOLUME XVI NUMBER 2 JULY/AUGUST 1964

Convair Traveler

*In This Issue: The DART-Convair*

OUR COVER

The sleek-looking Dart-Convair combines the Convair-Liner airframe of established structural reliability with the ultra-reliable Rolls-Royce Dart R Da. 10/1 engines. This combination provides outstanding improvements in performance, a restful cabin for greater passenger appeal, and increased revenue generating capacity at a cost that is considerably less than for comparable new equipment. The artist for this issue, George Paul.

# Convair Traveler

**VOLUME XVI NUMBER 2 JULY/AUGUST 1964**

MANAGER, CUSTOMER SERVICE—**O. W. HARPER**
CHIEF ENGINEERING SERVICE—**L. J. BORDELON**
CHIEF, FIELD SERVICE—**R. E. SOMMERS**
MANAGER, SERVICE PARTS—**J. DOIG**
MANAGER, TECHNICAL PUBLICATIONS—
**H. R. KENNEDY**
EDITOR—**GERTRUDE S. HUNTER**

**IN THIS ISSUE**

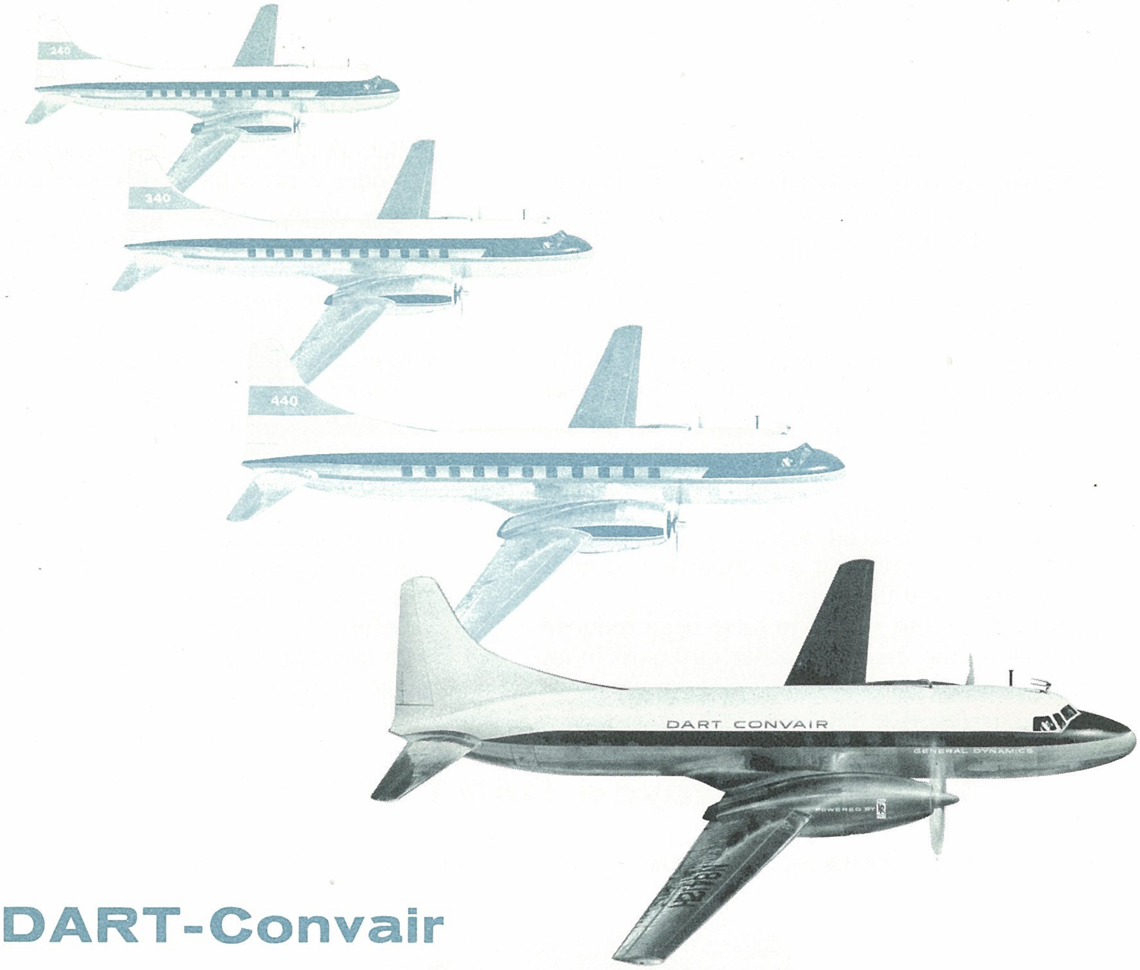
**PAGE 3**

THE DART-CONVAIR

A digest of operation and service published monthly by the Technical Publications Section of GD|Convair, primarily for the interest of Convair operators. Permission to reprint any information from this periodical must be obtained from the Chief of Technical Publications, General Dynamics|Convair, San Diego 12, Calif. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without the specific approval of their cognizant organization.

**COPYRIGHT 1964**

**GENERAL DYNAMICS CONVAIR**



# The DART-Convair

TURBOPROP POWER IS NOT NEW to the industry—it is not new to Convair. As early as 1946, during construction of the Convair 240, and during flight testing of a Convair 240 with turboprop engines in 1950, Convair engineers within limitations were plotting the future conversion to turboprop engines. They designed the airframe for growth in takeoff and landing weights. Also considered in the design were operating environment, route structure, landing frequency, and maintenance practices, all of which affect the efficient and useful life of the aircraft and its components. These aircraft were so designed that turboprop engines could be installed with a minimum of modification.

By the time fuel capacity was added, and the fuselage lengthened to accommodate another row of seats, Convair had a similar airplane but one that turned out to be essentially a new model—the Convair 340. This model was followed by the Metropolitan 440, which had some additional improvements in sound reduction and speed.

Conversion of Convair-Liner aircraft to turbine power is being offered in kit form to operators of these aircraft. By mating the proved structural airframe of the Convair 240/340/440 aircraft with the Rolls-Royce Dart R. Da. 10/1 engines of proved performance, the aircraft becomes one of the most useful profit-earning airplanes in an airline's inventory. With installation of these engines, operators can update their fleets with modern, high-performance transports at much less than the initial cost of comparable new turbine-powered equipment.

The Dart-Convair is capable of cruising at much higher speeds than is possible with reciprocating engines. Consequently, operators can continue to utilize their fleets of Convair-Liners, taking full advantage of the more powerful, ultra-reliable Rolls-Royce R.Da 10/1 gas turbine engines.

Convair has a good airplane in the Convair-Liner series; the proof is in the number of them in operation around the world. These aircraft have established the most impressive record in the history of air transportation. In the first ten years of operation, Convair-Liner aircraft logged seven million flight hours and made almost four and one-half million landings. The flight lengths were as low as 12 to 20 minutes, but the average flight ran to an hour and a half. Today, local service airlines average block times of 0.6 hour. This is a lot of hard usage, but the airplane was built to take it.

Updating the Convair-Liner series aircraft with Rolls-Royce Dart R. Da. 10/1 turboprop engines will provide operators with a modern high-performance transport capable of fifteen or more years of economical service life. This has been proved through extensive structural fatigue testing early in the Convair-Liner program, which 1) established areas of potential failures and the character and sequence of these failures so that any likelihood of failure could be detected by normal inspection before it became a safety consideration; and 2) determined the ability of the remaining structure to assume an overload upon failure of a weakened part.

With the addition of Dart engines, the problem of obsolescence facing piston-powered aircraft will be solved. The Dart-Convair will provide increased speed, reduced vibration, and a quiet restful cabin, factors that are important to both the passenger and the airline.

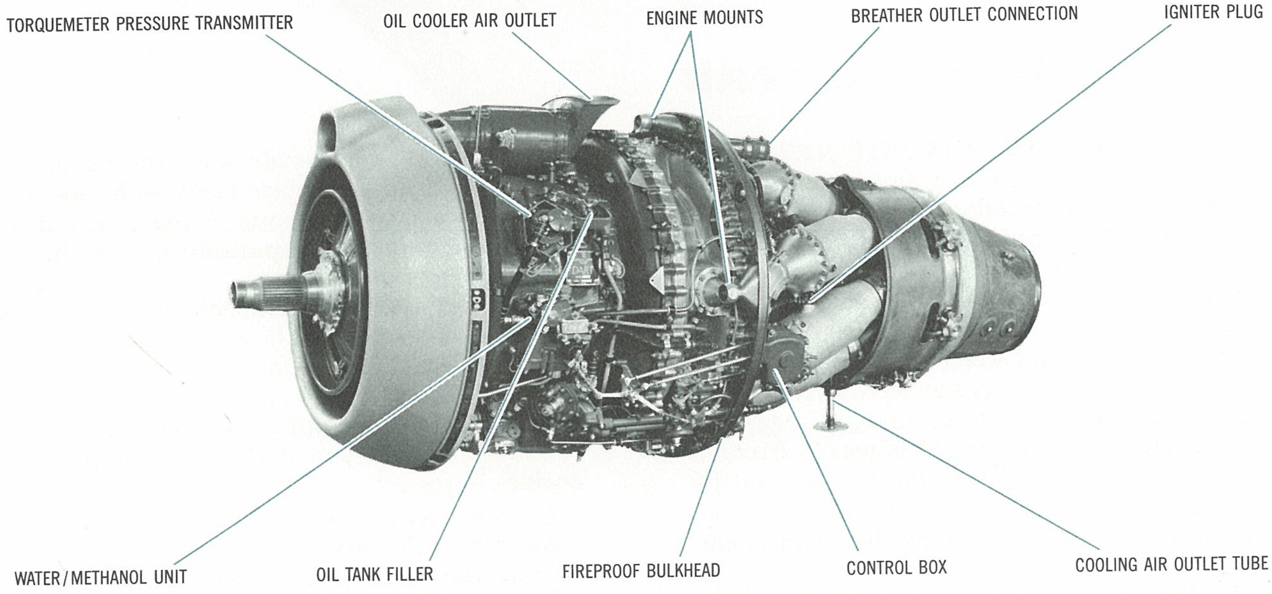
Cabin noise and vibration have been reduced by installing the engines farther outboard in an offset nacelle. This unique installation, plus propellers that are approximately six inches shorter, provides a propeller-to-fuselage clearance of 25 inches on the Dart-Convairs.

To further enhance the versatility and economy of the modified aircraft, the installation of an auxiliary turbine is being offered. The turbine will provide self-sufficiency in ground starting, auxiliary electrical power, and ground air conditioning.

Today, if anyone were to design and build a new turboprop airplane for local service or short range use, it would probably be just like a 440 with reliable turboprop engines, but at a very much higher capital investment.

No new airplane is being offered to local services, nor is one likely to be offered for some time, that will operate with full space limit payload, comfortably seating up to 54 passengers, and with the economy, reliability, versatility, and passenger appeal of the Dart-Convair.

## The Rolls-Royce DART R. Da. 10/1 Engine



GD/Convair, having studied several turboprop engines, chose the Rolls-Royce Dart R. Da. 10/1 engine for the most economical and effective Convair-Liner Modification. Reliability of the engine is well established. The Dart engine series has over 20 million hours in service; Dart engines are designed for economy of operation and maintenance; and overhaul time growth potential is excellent.

Dart engines are used by over 200 airlines in 47 countries, and there are 25 overhaul bases throughout the world.

The Dart has a takeoff rating, with water-methanol boost, of 2750 shaft horsepower, or 3025 equivalent horsepower (including exhaust thrust). Minimum takeoff power of the propeller shaft is 2750 SHP (less the maximum permitted through the accessory gearbox, which is 70 SHP at takeoff).

Air for the compressor is taken in through an annular intake at the nose of the cowling. An oil cooler air intake is located at the top of the annular intake.

The combustor is comprised of seven interconnected conical stainless steel combustion chambers with the nozzle box helically arranged around the engine casing. Each chamber has an expansion chamber, an outer air casing, a flame tube, and an atomizing fuel burner. Flame tubes are of heat-resistant Nimonic 75 alloy; high energy igniter plugs are fitted in two chambers; fuel burners are located so as to provide downstream injection.

The exhaust unit on the engine is not connected directly to the tailpipe. This arrangement is exactly as on all other Dart installations and has several advantages: it facilitates engine removal, provides ventilation airflow through the aft bay, and precludes distortion of the nozzle box and exhaust cone. The tailpipe extends aft over the wing, terminating in an oval duct.

The oil system, integral with the engine, is a self-contained recirculating unit. It provides pressure lubrication for bearings on the main shaft and reduction gear, and for the various drive gears and support bearings. Scavenge pumps return the oil to an oil cooler, which is mounted aft of the air intake duct. Oil is then directed to an aerator, from which it returns to the tank for recirculation. The pressure and scavenge pumps are driven from the reduction gear. The oil tank, reduction gear, and sump are connected so as to allow breathing through the hollow compressor shaft into the accessory drive housing.

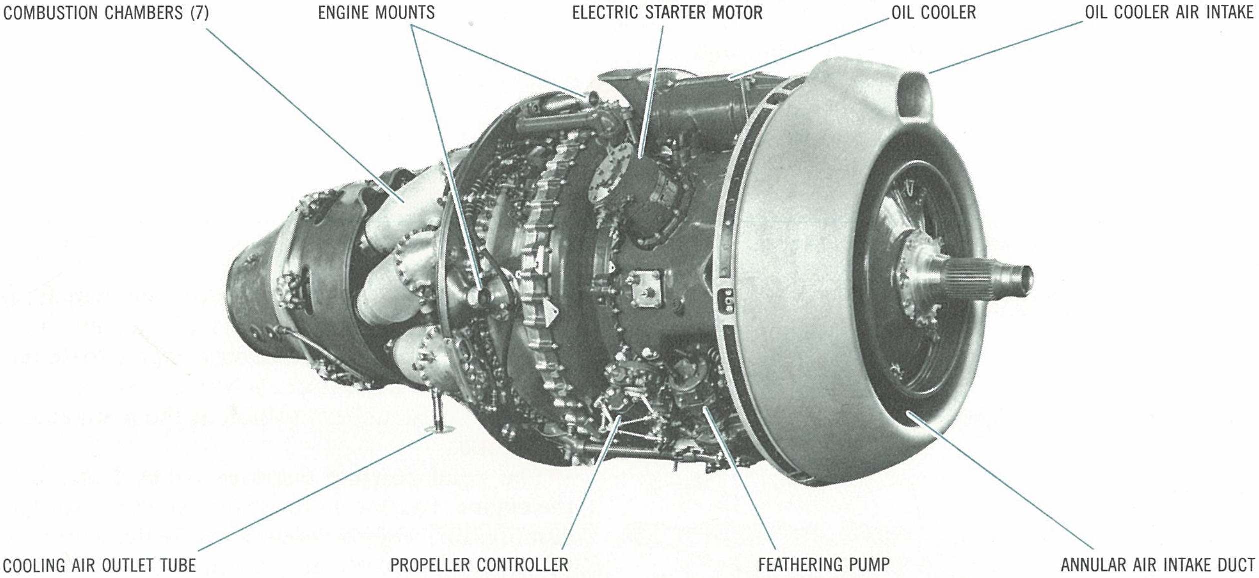
Rolls-Royce Dart engines are provided with a water/methanol injection system for boosted takeoff power as well as for maintenance of takeoff power at elevated temperatures. Water/methanol for the Dart engine installation is required only when altitude, temperature, and loading conditions demand. The system includes several items of equipment: a 60-gallon vented storage tank in each wing spar box section, for either gravity or pressure filling; an electric-motor-driven pump, an electric-driven shut-off valve for each engine, a line-mounted filter, a water/methanol regulator on each engine, a green light to indicate satisfactory fluid pressure at the regulator inlet, a pressure switch for operation of the fluid pressure indicator light, and a water/methanol quantity transmitter in each tank.

A cross-feed system permits interconnecting the supply to either engine in case of pump failure.

Included in the demountable power plant assembly are the engine mount, engine-mounted accessories, engine oil system, and propeller. This assembly can be used in either the left- or right-hand nacelle without modification or adjustment of engine controls.

A shaft-driven accessory gearbox—also interchangeable between nacelles—is installed on the nacelle firewall to permit removal of the engine without removing the gearbox.

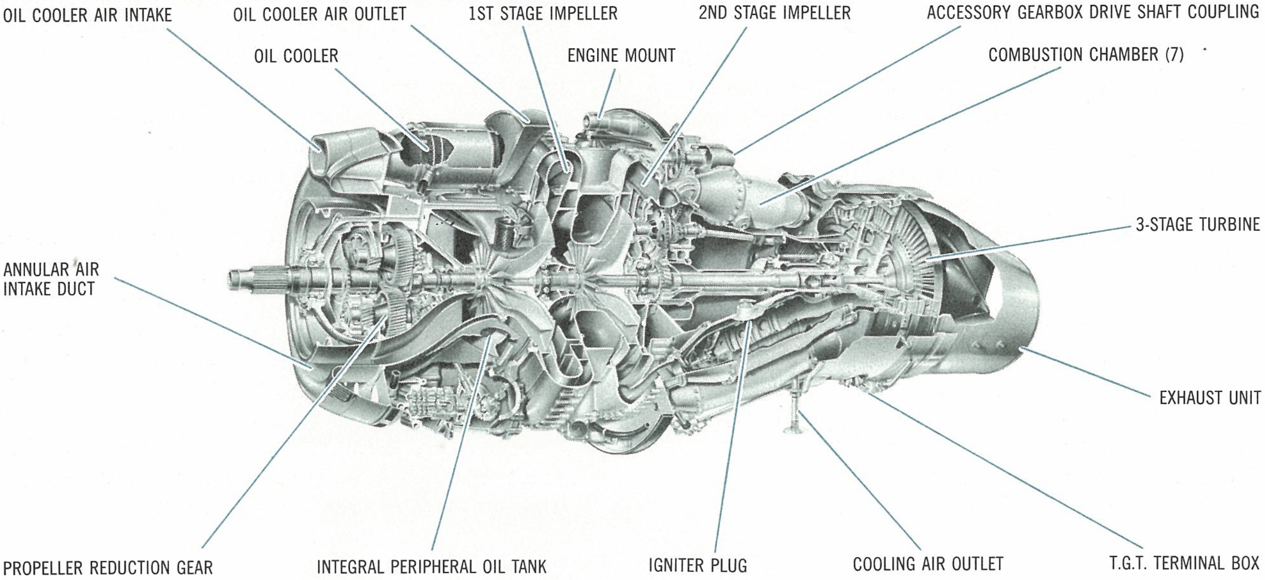
The cabin air compressor, AC and DC generators, tachometer generators, and the main hy-



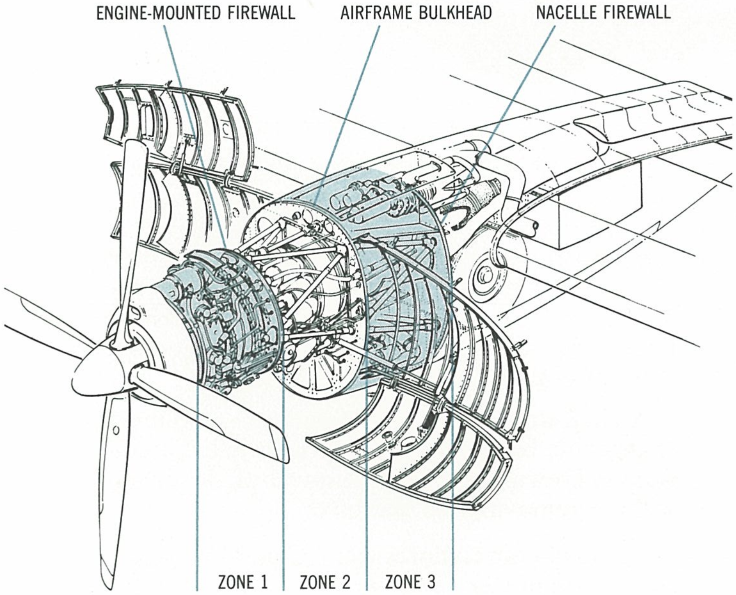
draulic system pumps are operated from the accessory gearbox.

One DC and one AC generator are mounted on the generator drive pads of the accessory gearbox in each nacelle. Existing DC generators may be used. A new 15-kva AC generator for each engine is required to supply power for the propeller, spinner, and engine intake anti-icing, and to provide emergency power for the flight instruments.

Combustion heaters are installed forward of each nacelle firewall for heating the cabin, and for wing and tail anti-icing.



## Engine Cowling



Engine cowling, consisting of four panels, is hinged at the airframe firewall and attached at the forward end with quick-release toggle fasteners and a safety lock feature. When closed, the cowling rests on a rubber cushion at the main engine air intake.

The petal cowling encloses zones 1 and 2 of the engine. In zone 1 are the two-stage centrifugal compressor, engine mounts, propeller controls, oil tank, oil cooler, oil transmitter, oil and fuel pumps, and the torquemeter. In zone 2 are the combustion heaters, nozzle box and igniters, breather outlet, fuel heater, and engine mount fittings.

Zone 1 is separated from zone 2 by a steel firewall to provide a fire seal between the two zones.

Aft of the airframe bulkhead in zone 3 is the exhaust unit which is comprised mainly of the tailpipe and the accessory drive gearbox. Access to this area is through removable panels in the nacelle structure. To accommodate the exhaust tailpipe, a new overwing structure is required; the present nacelle firewall can be modified to accommodate the tailpipe.

# The Propeller

The Dowty Rotol propeller is a four-bladed, variable pitch unit that is hydraulically operated and electrically controlled. The blades are solid dural with rounded tips. Diameter of the propeller is 13 feet, providing a ground clearance of 14.9 inches and a fuselage clearance of 25 inches on the Dart-Convairs.

The propeller is driven from the engine reduction gear which transmits torque to a rotating annulus gear on the propeller shaft. Propeller gear ratio is 0.0775 times engine speed.

Fuel flow and selected rpm are interconnected in such a manner that for a given fuel flow setting there is a corresponding selected rpm, thus giving optimum operating economy under varying conditions.

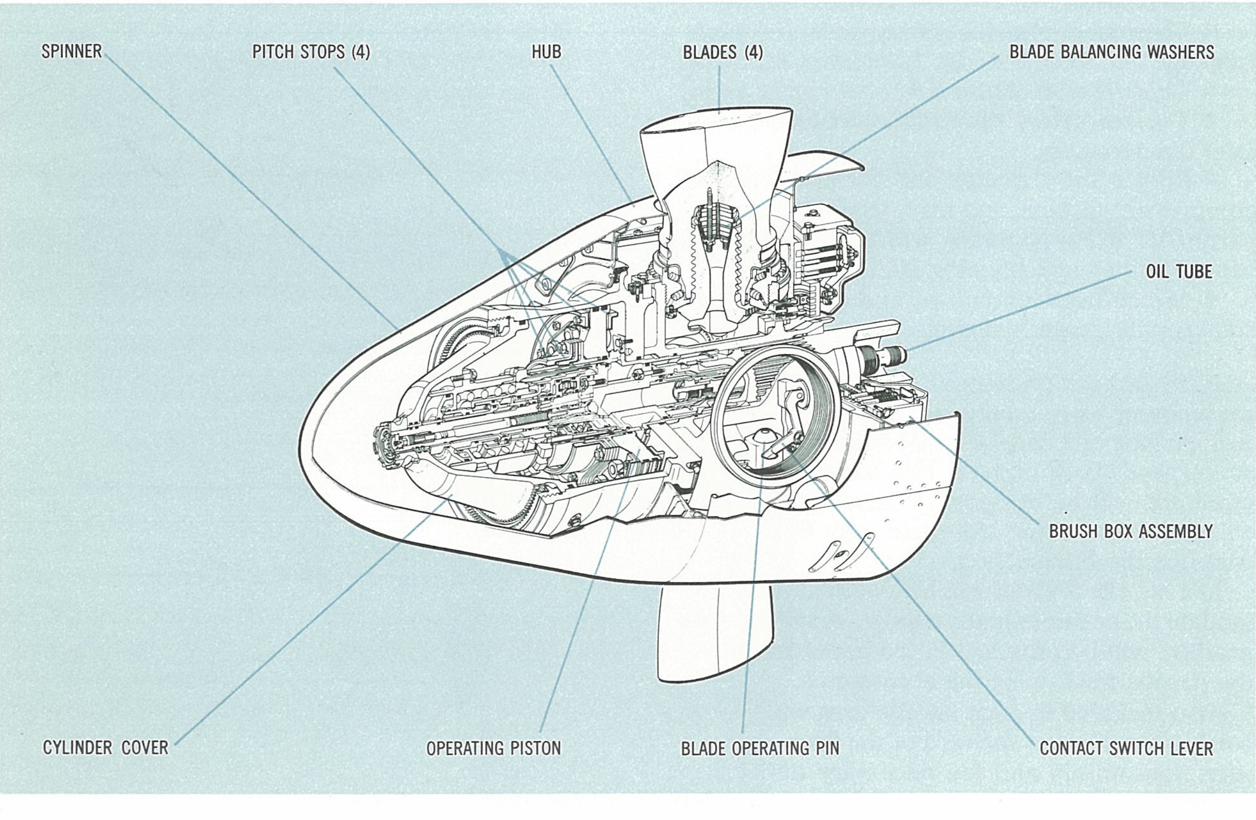
The controller unit consists essentially of a gear-type pump mounted on and driven by the engine, boosting engine oil under pressure via a flyweight actuated valve. This valve directs oil under pressure to the propeller pitch-changing mechanism in the propeller hub.

The propeller variable speed control maintains a constant selected speed in a range of 11,000 to 15,000 engine rpm. An overspeed governor incorporated in the fuel pump takes over control of engine speed in event of failure of the propeller control unit or overspeeding of the propeller. In event of engine failure, the pitch is automatically increased (propeller feathered) by a torque sensitive pitch-increasing system, taken from the engine torquemeter.

Pitch range of the propeller is limited by a fixed abutment type stop at the feather and 0° positions. Removable stops are provided at cruise and flight fine positions.

The propeller blades and spinner are electrically de-iced. The leading edge of the blade is recessed for a distance of approximately nine feet from the hub to accommodate a rubber shoe, which contains the heating elements. The shoe is faired into the leading edge to maintain aerodynamic efficiency.

Similar heaters are fitted to the interior of the light alloy nose spinner which encloses the propeller hub and pitch change mechanism.



# Areas of Modification

Installation of Rolls-Royce Dart Engines and Rotol propellers will not require modification of the 340/440 airframe. Major areas of change are in the nacelles and flight compartment instrumentation, with some minor changes in fuel, fire extinguishing, hydraulic, cabin pressurization, anti-ice and cabin heat, electrical, and starting systems. Local reinforcement of the 240 basic airframe structure will offer operators an aircraft with greater landing and takeoff weights.

General areas of modification are as follows:

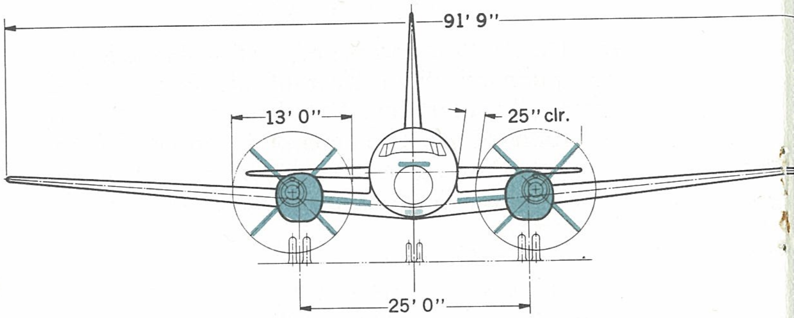
*ROLLS-ROYCE R.Da. 10/1 ENGINE,* which includes:

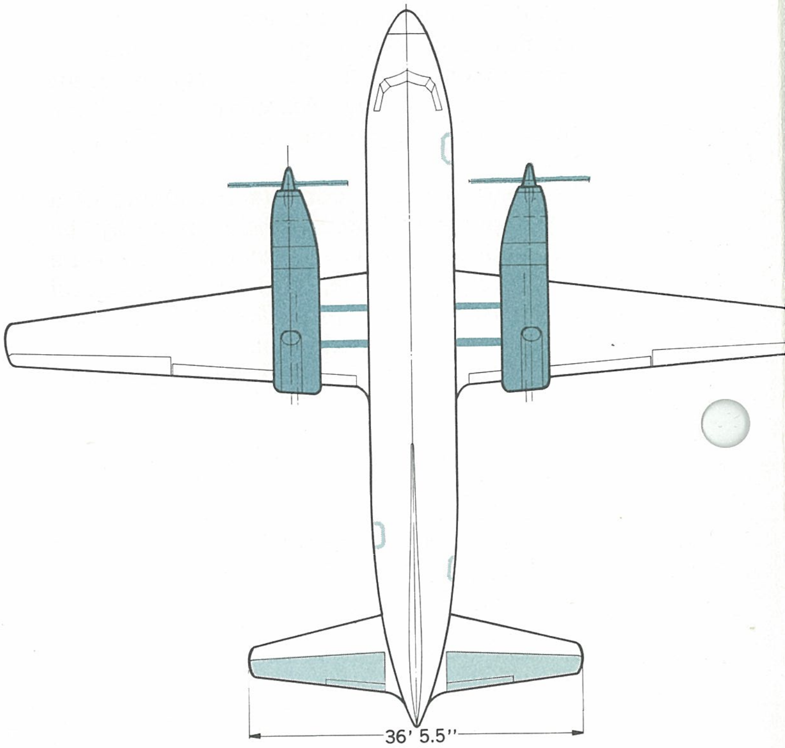
- Nose cowl, including engine air intake system and oil cooler air intake.
- Propeller and spinner extension, with electrical de-icing junction box.
- Engine oil system including oil tank, oil cooler, oil pressure transmitter, and oil temperature bulb.
- Fuel pump and fuel control unit.
- High-energy igniter plugs, and starter.
- Water/methanol regulator.
- Engine exhaust cone.
- Pressure transmitters for oil and torque measurement.
- Thermocouples for jet temperature measurement.
- Throttle trim actuator.
- Thermometers for turbine cooling and oil inlet temperatures.
- Edison fire detector unit for protection of compressor, turbine, and main landing gear compartments. New plumbing will be routed to the supply bottles in each wing fillet.
- Miscellaneous valves and controls with cables, pulleys, and brackets.

*NACELLE.* A new nacelle structure forward of the airframe will be required. This nacelle section will include the hinged cowl panels, air intake scoop, and drain outlets. The nacelle overwing structure will be designed to accommodate the exhaust tailpipe and will mate with the original wing/nacelle intersection.

The nacelle firewall will be modified to accommodate the engine exhaust tailpipe. A shaft-driven gearbox will be provided in the upper portion of the nacelle for driving the accessories.

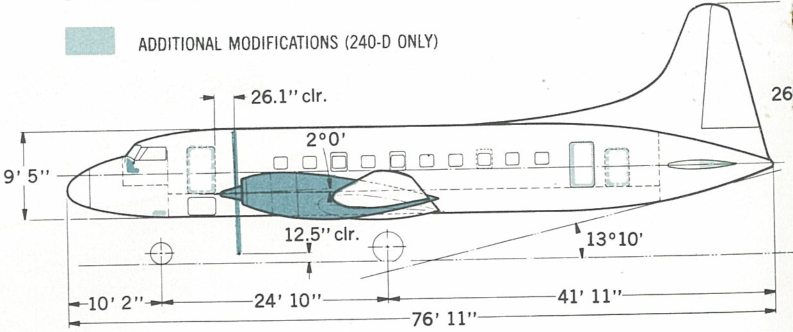
Also included in each nacelle area will be two combustion heaters forward of the firewall; pressure transmitters and the necessary tubing and wiring.





■ AREAS OF MODIFICATION

▒ ADDITIONAL MODIFICATIONS (240-D ONLY)



The air conditioning and pressurization systems will remain essentially the same except for new ducting, dump valves, and a manifold system for connecting the combustion heaters to the existing cabin heat and wing and tail anti-ice ducting. By use of combustion heaters, ground cabin heating is available without running the engines. On airplanes utilizing an APU, additional changes will be required.

*WING*. Each wing spar box will contain a 60-gallon lightweight vented storage tank for the water/methanol system. Each tank will be connected to supply either engine through an interconnected crossfeed system. A filler neck and pressure filling connection will be provided on the lower wing surface. Included in the water/methanol system will be an electric-motor-driven pump, a line-mounted filter, a regulator, and a quantity transmitter in each tank.

*INSTRUMENTATION*. Modification of the flight compartment controls and instrumentation will involve engine instruments on the center instrument panel, revisions in power levers on the pedestal, and modification of the overhead switch panel. Included are other detailed changes required to accommodate turbine type engines, propellers, and systems equipment. A configuration similar to other Dart-powered aircraft is realized.

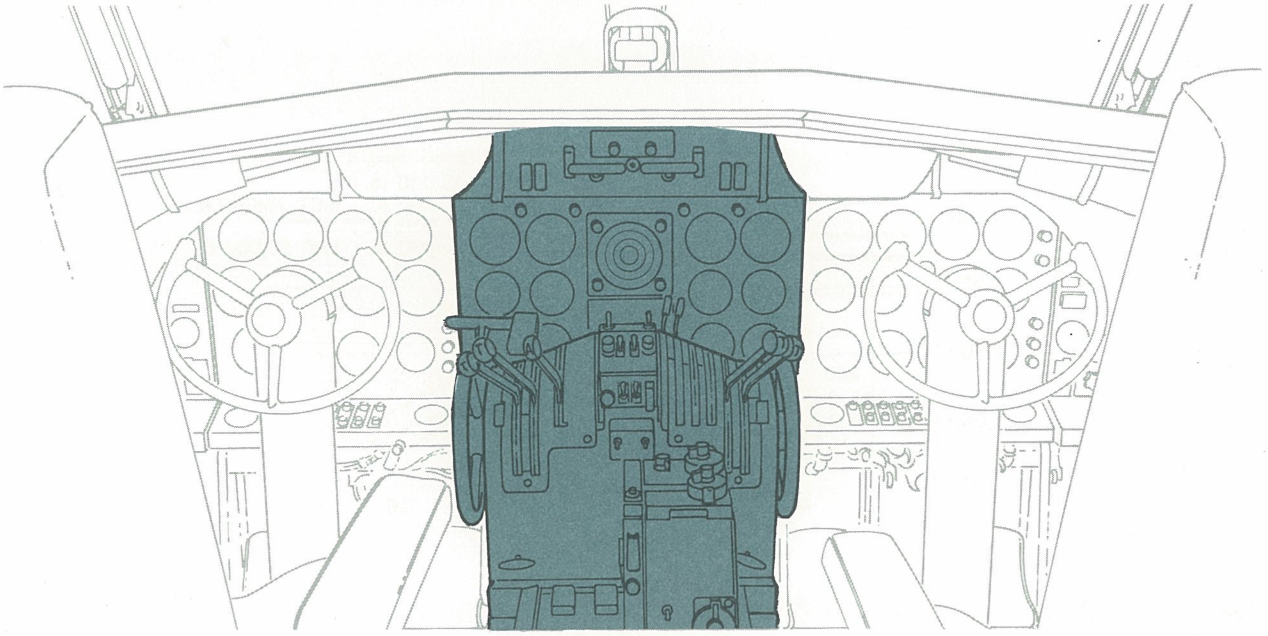
*AUXILIARY POWER UNIT*. A separate kit for installation of a gas turbine APU to drive the 500-amp DC generator and the cabin air compressor will be made available. This installation will be covered in detail in a subsequent issue of the Traveler.

*STRUCTURAL REINFORCEMENT*. On the Convair 240 only, local reinforcement of the fuselage in the areas of the forward and aft entrance and service doors and emergency exits forward and aft of the wing may be required for increasing zero fuel weight for added payload. Wing structure, inboard of the nacelles, and the nose wheel well structure will require reinforcement to permit higher maximum landing weight on the 240D.

The following Convair 240 Service Bulletins will require incorporation prior to or concurrent with installation of the 240 Dart modification kit.

| | |
|---|---|
| 240-176A | Empennage – Reinforcement of elevator leading edge ribs, and rework of elevator/rudder balance weights. |
| 240-19 | Elevator – Addition of nose rib gussets and provisions for fourth hinge. |
| 240-247A | Empennage – Rework. |
| 240-268 | Empennage – Reinforcement of inboard elevator leading edge ribs. |
| 240-308B | Gross weight Modification – 41,200 lbs. Changes in landing gear, structural additions, and installation of outer wing panels for additional fuel-carrying capacity. |
| 240-426 | Nose Landing Gear – Beef-up of beam. |

On the Convair 340, Service Bulletin 340-217 should be incorporated prior to, or concurrent with, installation of the 340 Dart kit, if higher gross weight is to be used. Bulletin 340-217 modifies the landing gear brake systems.

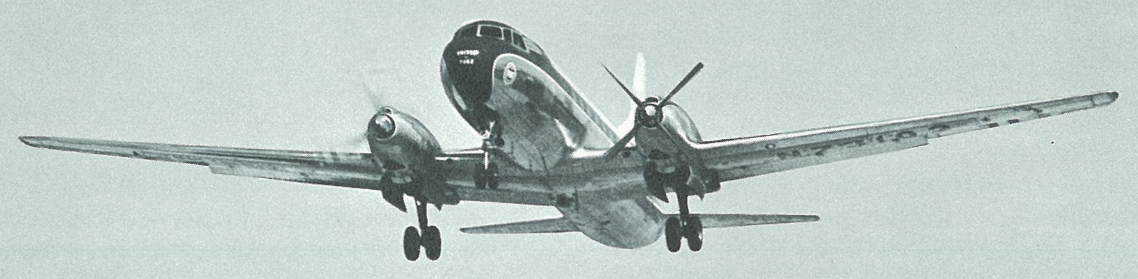


# Performance

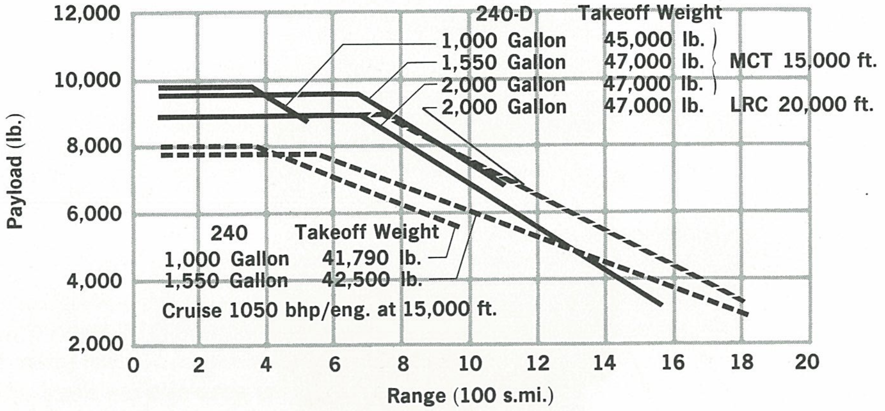
The conversion to turboprop engines has been specifically designed to meet airline requirements for a higher speed short-range transport that will achieve low operating cost per airplane mile and increase short-range flexibility.

Convair-Liner operators will realize increased performance as well as economy, dependability, and passenger appeal with the smoother, quieter Dart-Convair. Increased takeoff power will mean shorter runways for a given gross weight, or increased gross weights at available runway lengths. The Dart modification reduces the basic weight 800 to 2000 lb, depending on airplane configuration. Increased takeoff and landing weights permit practically unrestricted operation. These factors give operators added potential gross income with a decrease in operating cost.

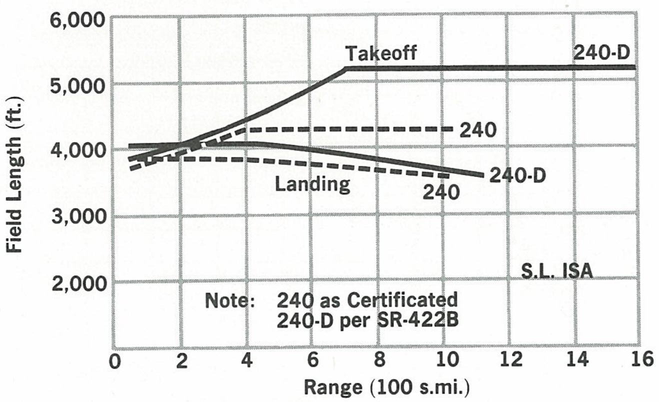
The Dart-Convair can operate economically on short-to-medium route segments, making it the most versatile short-to-medium range aircraft available to operators. It can fly economically at any altitude between sea level and 20,000 feet, enabling it to avoid rough weather. The increased cruising speed (50 mph) and improved engine reliability of the modified aircraft will permit higher utilization and generate more revenue at lower, direct operating costs while combining passenger appeal with greater operational flexibility.



## 240-D

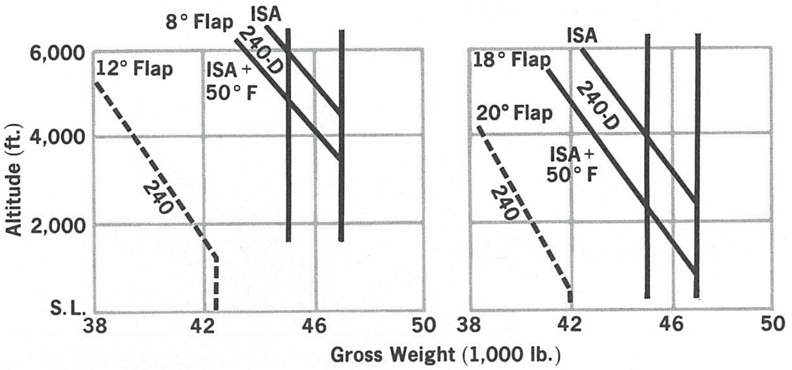


**Payload vs. Range**



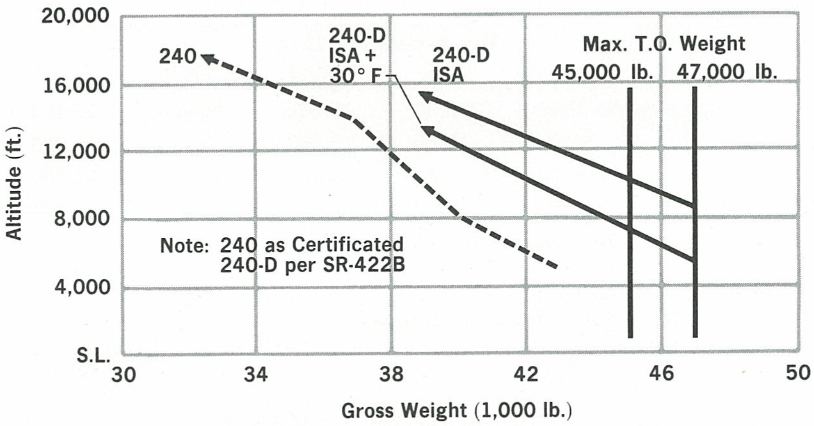
Note: 240 as Certificated
240-D per SR-422B

**Range vs. Field Length**



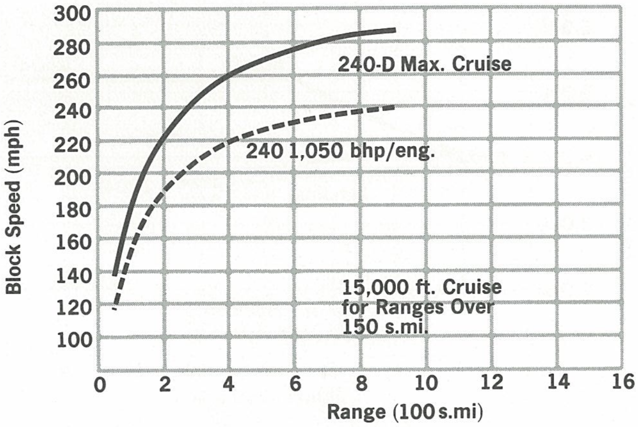
Note: 240 as Certificated
240-D per SR-422B

**FAA Climb Limits**



Note: 240 as Certificated
240-D per SR-422B

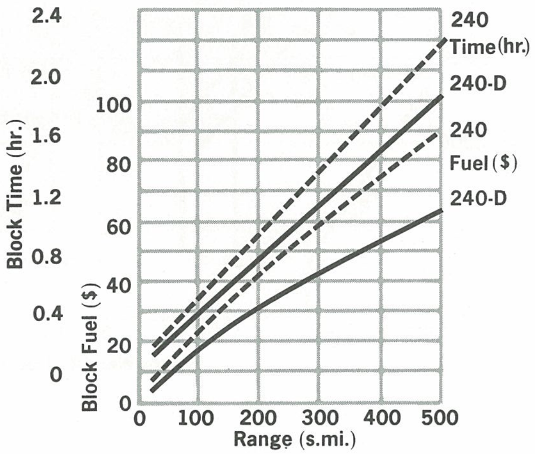
**FAA En Route Climb Limits**



## Block Speed vs. Range

Notes:

1. 240: 1,050 bhp/eng.
   Fuel - 5.8 lb./gal.
   & 20.5¢/gal.
2. 240-D: Max. Cruise
   Fuel - 6.7 lb./gal.
   & 11¢/gal.
3. 15,000 ft. Cruise
   for Ranges Over
   150 s.mi.



## Block Fuel & Time vs. Range

Typical Wt. (lb.)

| | Max. Payload (Wt. Limit) | | Max. Fuel Limit | |
|---|---|---|---|---|
| | 240 | 240-D | 240 | 240-D |
| Operating Wt. Empty | 30,400 | 29,600 | 30,400 | 29,600 |
| Payload | 7,900* | 9,700** | 5,590 | 8,700 |
| Operating Zero Fuel | 38,300 | 39,300 | 35,990 | 38,300 |
| Fuel (1,000 U.S. Gal. Max.) | 3,490 | 6,100 | 5,800 | 6,700 |
| ***Takeoff Gross Wt. (Max.) | 41,790 | 45,000 | 41,790 | 45,000 |

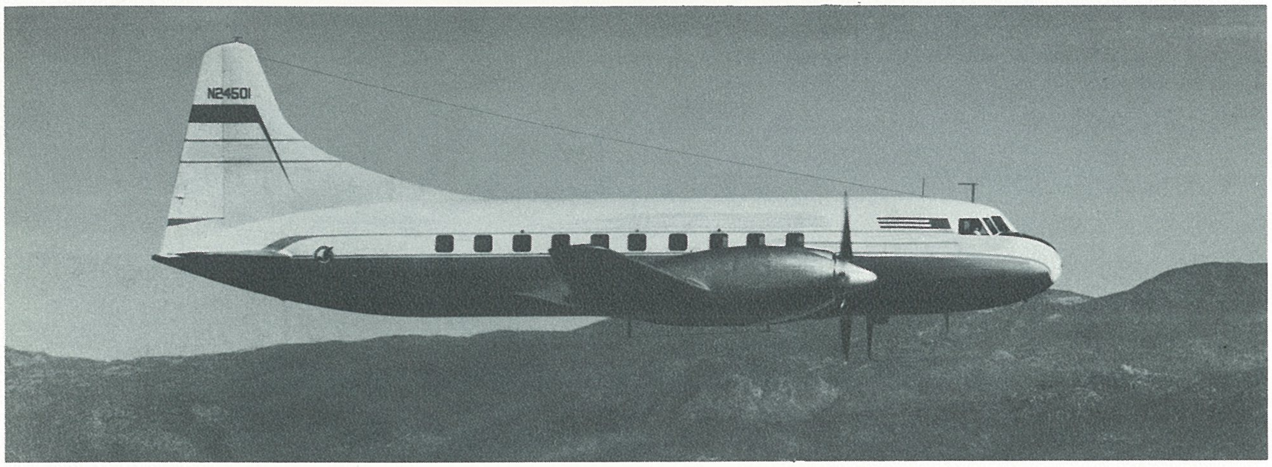
*Limited by 39,800 lb. Max. Landing Wt. (with 1,500 lb. Reserve)

**Limited by 39,300 lb. Max. Zero Fuel Wt.

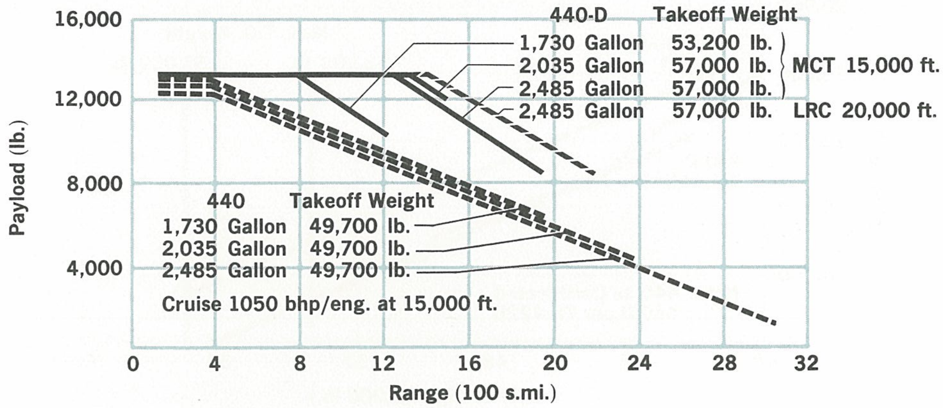
***Max. T.O. Gross Wt. of 240-D with Outer Wing Fuel and Fuel Dumping Increased to 47,000 lb.

Note: Max. Landing Wt. of 240-D Increased to 44,000 lb.

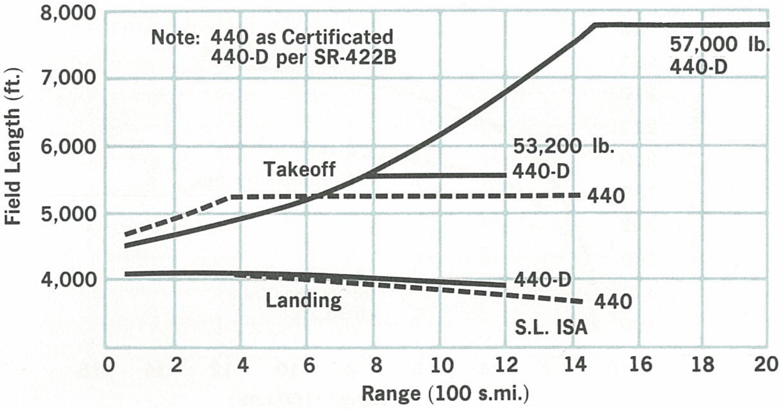
## Weight Comparison



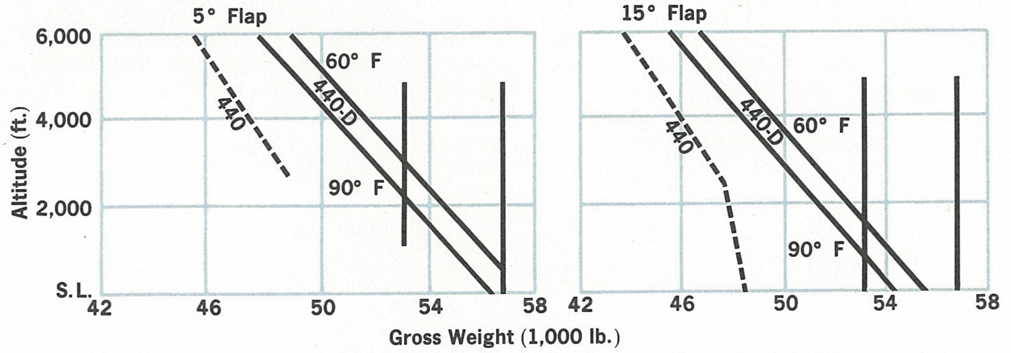
# 340/440-D



## Payload vs. Range

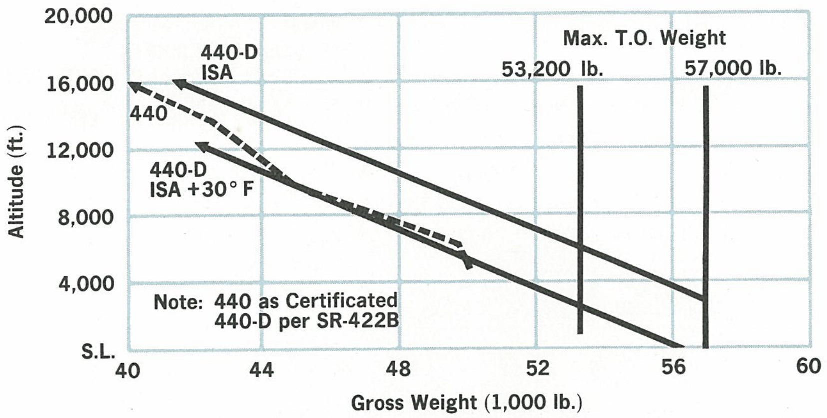


## Range vs. Field Length

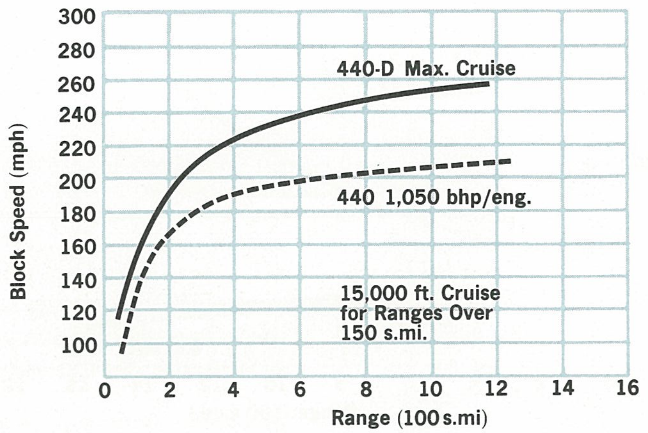


Note: 440 as Certificated
440-D per SR-422B

## FAA Second-Segment Climb Limits



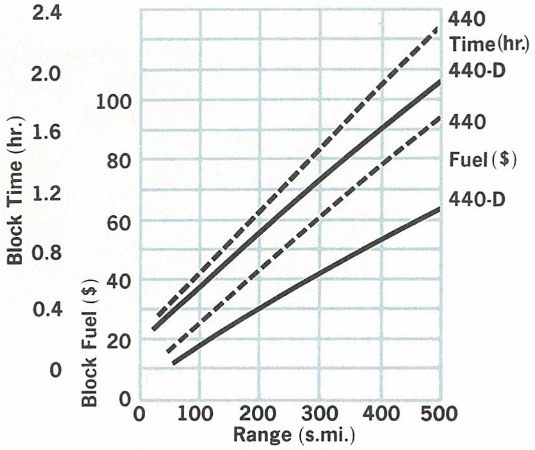
## FAA En Route Climb Limits



## Block Speed vs. Range

Notes:

1. 440: 1,050 bhp/eng.
   Fuel - 5.8 lb./gal.
   & 20.5¢/gal.
2. 440-D: Max. Cruise
   Fuel - 6.7 lb./gal.
   & 11¢/gal.
3. 15,000 ft. Cruise
   for Ranges Over
   150 s.mi.



## Block Fuel & Time vs. Range

| | Typical Wt. (lb.) | | | |
|---|---|---|---|---|
| | Max. Payload (Wt. Limit) | | Max. Fuel Limit | |
| | 440 | 440-D | 440 | 440-D |
| Operating Wt. Empty | 33,200 | 31,200 | 33,200 | 31,200 |
| Payload | 12,950* | 15,800** | 6,500 | 10,400 |
| Operating Zero Fuel | 46,150 | 47,000 | 39,700 | 41,600 |
| Fuel (1,730 U.S. Gal. Max.) | 3,550 | 6,200 | 10,000 | 11,600 |
| ***Takeoff Gross Wt. (Max.) | 49,700 | 53,200 | 49,700 | 53,200 |

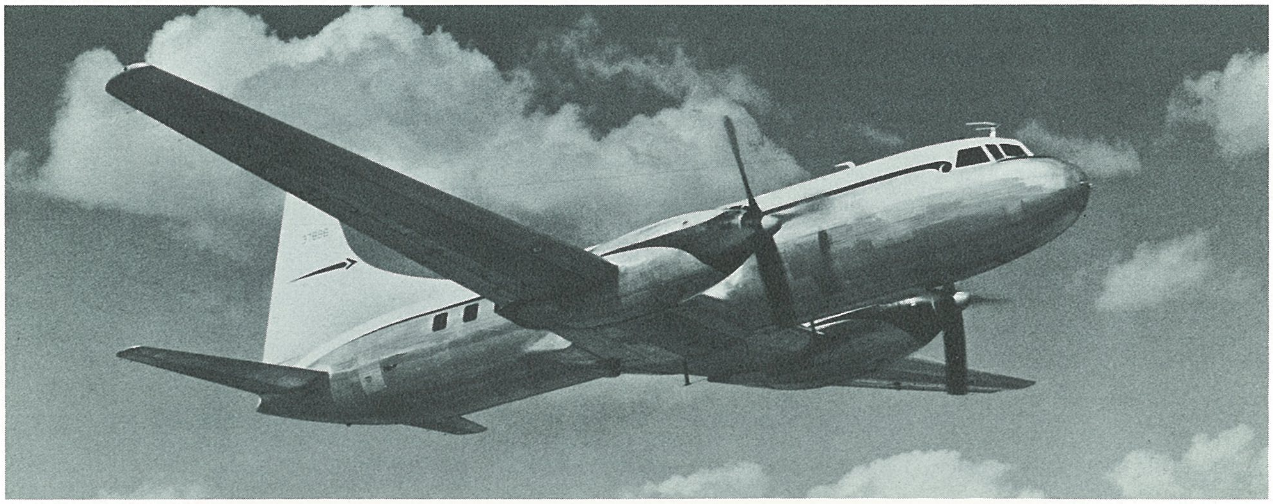
*Limited by 47,650 lb. Max. Landing Wt. (with 1,500 lb. Reserve)

**Limited by 47,000 lb. Max. Zero Fuel Wt.

***Max. T.O. Gross Wt. of 440-D with Outer Wing Fuel and Fuel Dumping Increased to 57,000 lb.

Note: Max. Landing Wt. of 440-D Increased to 50,670 lb.

## Weight Comparison



6 40

# SERVICE IS OUR MOST IMPORTANT ASSET

THE SERVICES of a special Convair customer service unit will be available to the customer to assist him in the modification of the Convair-Liner aircraft to accept Rolls-Royce Dart engines. The project also includes a training program on the operation and maintenance of the modified aircraft.

Rolls-Royce, with 25 overhaul and support bases throughout the world, will lend prompt aid in the maintenance, operation, and spare parts provisioning of the power plant unit.

Convair will provide technical and parts support of the aircraft converted to Dart engines as well as continued support of unmodified aircraft. A coordinated service team of specialists will be available when required or requested.

Specialists may come from one department or from several departments, depending on the type of service required. In any event, they function as a team, coordinating the efforts, performance, and functions of their particular groups and those of other groups, when needed, to accomplish one objective—SERVICE to the customer.

This team effort has been proved through the years, and most recently when a Convair 880 made an ILS landing on an ice- and slush-covered runway during minimal weather.

The fact that this happened on a holiday when factories and most places of business were closed did not affect the services of the Convair team. The Convair area service engineer immediately left for the scene of the accident; from a brief description of the incident, Service Parts personnel began determining the extent of damage and the parts that would be required to repair the airplane; the shipping department began packing these parts and assemblies.

Two days later, when the airplane had been moved into the hangar and the damage evaluated with the assistance of a Convair structures engineer and a Service Parts representative, many of the necessary parts were already en route.

The GD/Convair team, anticipating problems in the repair of the airplane, dispatched a tooling representative and a shop foreman to assist airline personnel. On the recommendation of the Convair representatives, the necessary tools were loaned to the airline to facilitate structural repairs and replacement.

Since Convair Service Parts Department maintains a reliable range of accident-vulnerable structural members, as well as a full supply of high usage items, there was no delay incurred in the shipment of the necessary parts.

Although Convair jet airliners and, of course, the Convair-Liner are no longer in production, operators may feel assured that Convair will continue to maintain sufficient parts inventory to support these aircraft in the field.

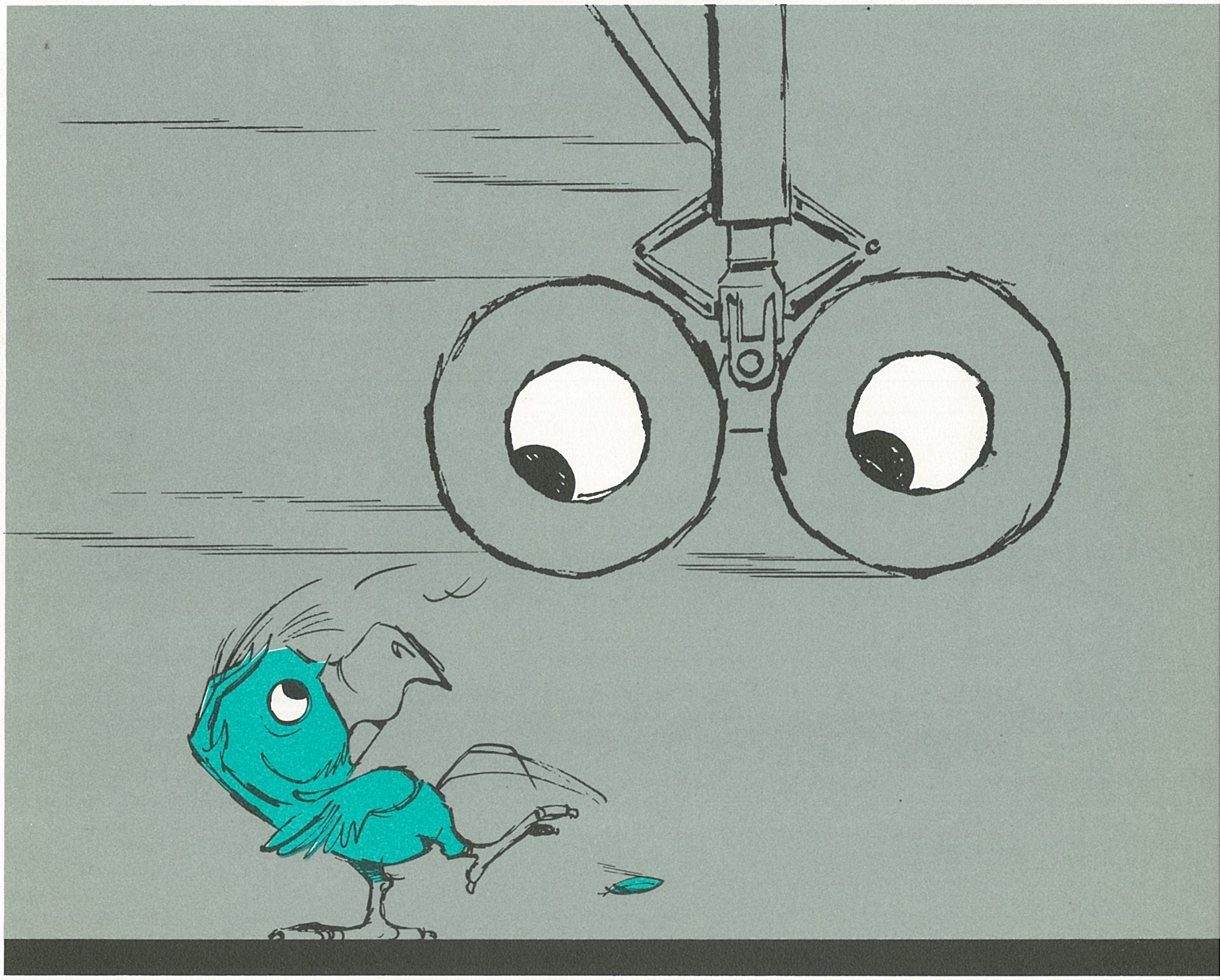
The service team, in the performance of its function, will continue to act as a bond, or connecting link, between GD/Convair and the operator. The men on the team will be available around the clock for consultation, advice, and assistance. Convair is as eager as the operator to make the airplane a smooth operating piece of equipment.

Capability is maintained to meet any emergency with a minimum delay for preparation, whether the request comes from the Convair Field Service Engineer or from the customer. Each member on the Convair team of specialists is devoted to the same general goal—the ultimate in SERVICE to the customer.

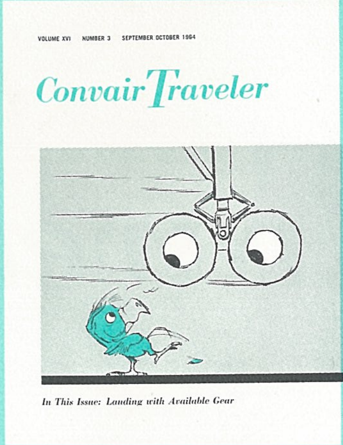
GENERAL DYNAMICS | CONVAIR

VOLUME XVI NUMBER 3 SEPTEMBER|OCTOBER 1964

# Convair Traveler



In This Issue: Landing with Available Gear



VOLUME XVI NUMBER 3 SEPTEMBER OCTOBER 1964

Convair Traveler

In This Issue: Landing with Available Gear

OUR COVER

Willis Goldsmith, artist and creator of Earl E. Bird, gives a light touch to an important subject—"Landing with Available Gear." Earl E. Bird disports through the article, gracefully landing on his nose or belly to show the pilot how it's done. Convair jet airliner pilots please take note.

# Convair Traveler

**VOLUME XVI NUMBER 3 SEPTEMBER/OCTOBER 1964**

MANAGER, CUSTOMER SERVICE—**O. W. HARPER**
CHIEF, FIELD SERVICE—**R. E. SOMMERS**
MANAGER, SERVICE PARTS—**J. DOIG**
MANAGER, TECHNICAL PUBLICATIONS—
**H. R. KENNEDY**
EDITOR—**GERTRUDE S. HUNTER**

**IN THIS ISSUE**

**PAGE 3**

LANDING WITH AVAILABLE GEAR

**PAGE 6**

FOAMING THE RUNWAY

**PAGE 8**

STRUCTURAL INSPECTION AFTER HARD LANDINGS AND FLIGHT INCIDENTS

**PAGE 10**

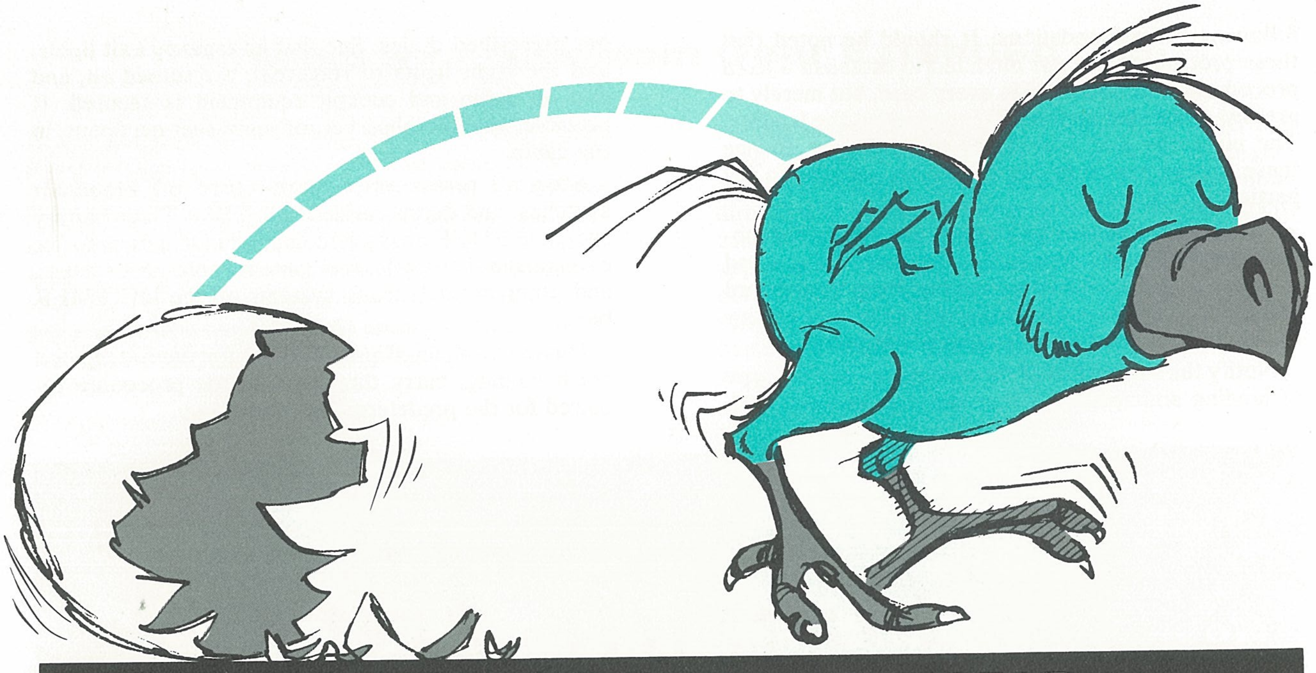
TEFLON HOSE ASSEMBLIES CARE AND HANDLING

**BACK COVER**

TORQUE SENSE

A digest of operation and service published monthly by the Technical Publications Section of GD|Convair, primarily for the interest of Convair operators. Permission to reprint any information from this periodical must be obtained from the Manager of Technical Publications, General Dynamics|Convair, San Diego, Calif., 92112. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without the specific approval of their cognizant organization.

**COPYRIGHT 1964**



# LANDING WITH AVAILABLE GEAR

THE AIRPLANE DESIGNER considers the landing gear a parasite because of its weight, the space required to house it, and the drag created when it is extended. But, until a suitable substitute is forthcoming, the landing gear is here to stay.

The advent of relatively high-speed, high-altitude aircraft served to bring into sharp focus each of the objectionable features of the landing gear, with particular emphasis on parasitic drag forces. The elimination of drag imposed on the airplane in flight with the landing gear extended was overcome by folding the gear into the wings when the airplane was airborne. Unrestricted airfoil design was achieved by covering the landing gear wells with faired doors. In today's jet aircraft, the wing is rapidly "vanishing"—it is becoming thinner and shorter so that there is no longer any room for the landing gear, and it must be housed in the fuselage when retracted.

The increased operating speeds of the jet airplane have made it even more imperative that the landing gear be retracted as soon as the airplane becomes airborne to eliminate parasitic drag, and that it be extended a short time before touchdown. To accomplish rapid extension and retraction, considerable power with "push-button" control is necessary.

Most of the elaborate systems and mechanisms incorporated in today's near supersonic transport aircraft are operated by the pilot's manipulation of switches and levers. The pilot extends flaps or speedbrakes, applies wheel brakes, and raises and lowers landing gear by remote control of hydraulic, pneumatic, or electrical power, singly or in combination.

And, the pilot doesn't have to depend completely on one power source to perform an important function. If it should fail he has an alternate system, or standby source of power.

Extension and retraction of the landing gear is accomplished by a combination of hydraulic and mechanical forces. In Convair jet airliners, mechanically moving the control handle to DOWN, ports hydraulic pressure to lower the doors; this movement mechanically actuates the landing gear sequence valve to unlatch the gear uplock and to lower the gear. Gear retraction is essentially a reverse of this operation.

The standby system of operation—or emergency operation—is by a combination of pneumatic and mechanical operation. Accumulator air pressure opens the doors; the emergency gear-down handle, in the first third of travel, ports hydraulic pressure to return and at the same time opens an air valve to unlatch and open the doors and to hold them open with air pressure. The second segment of travel of the emergency lever mechanically unlocks the door latches in the event of failure of the pneumatic system to operate; the third segment of travel mechanically actuates the main and nose gear uplatches, allowing the gear to free-fall.

If, for any reason all of the gear cannot be lowered, it may be necessary to make an emergency landing with any available gear. As of this writing, no Convair jet airliner has had to make any kind of gear-up landing. Convair has made some predictions and recommendations on gear-up landing procedures; however, they are more in the nature of opinions than positive recommendations, because such landings have not been substantiated by actual tests or incidents.

Several years ago, the Air Force and Navy, after lengthy analysis of landing incidents and accidents, directed their pilots to extend any gear they could, in any kind of landing emergency.

Based on military data, Convair estimates, and the probable patterns of rollout, Convair has made the following recommendations. It should be noted that these procedures are *not* intended to establish a *fixed* procedure to be followed in every case, but merely to present a possible method of carrying out the landing. The pilot may find it desirable to modify or change these procedures to fit circumstances peculiar to the particular incident.

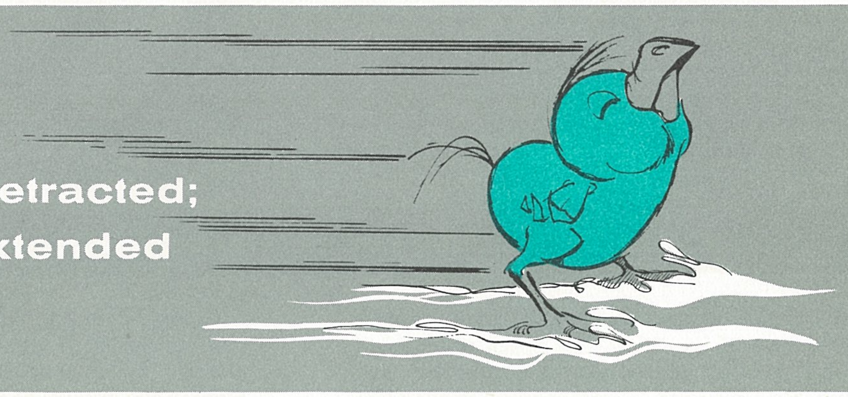
For any kind of gear-up landing, use a prepared runway; have it foamed, if possible. (Foaming is discussed later in this issue.) Scavenge the fuel from the inboard and center tanks, and jettison fuel as necessary to lessen the hazard of an emergency landing.

Notify the stewardess of the emergency and the type of landing anticipated so that she may proceed with her prescribed duties. See that emergency exit lights, and the night lights (if required), are turned on, and that all cabin and cockpit equipment is secured. If possible, seat the observer, or jump seat occupant, in the cabin.

Stop all turbocompressors, turn off bleed air switches, and depressurize the airplane. Place battery switch in EMER position to maintain DC power to fire extinguishing controls, fuel system valves, PA system, and other miscellaneous systems on the DC EMER bus.

Having completed preparations for the anticipated crash landing, carry through with the procedure required for the predetermined emergency.

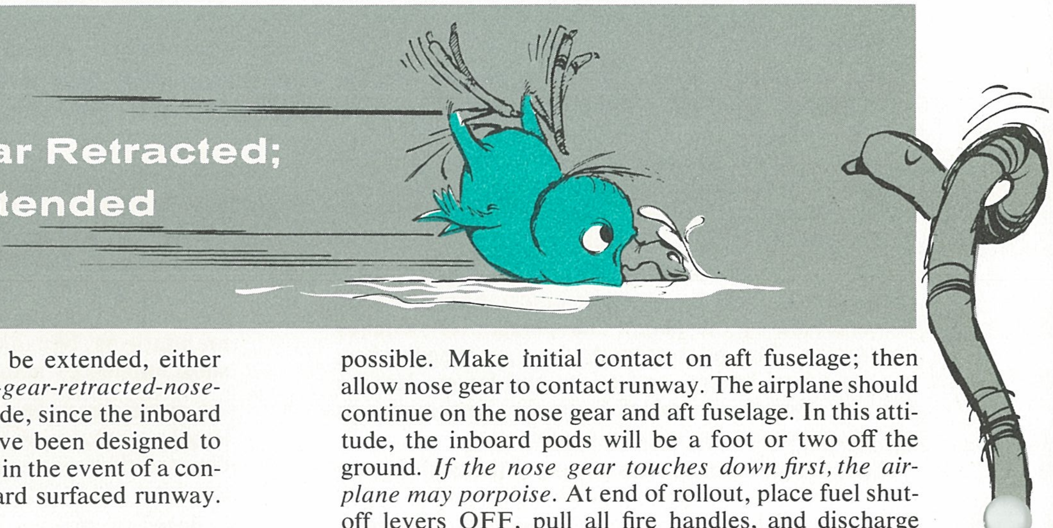
## Nose Gear Retracted; Main Gear Extended



Move passengers as far aft as possible. Set wing flaps at full down, and make normal approach, landing flare, and touchdown. After touchdown, extend spoilers. Retract wing flaps at 110 knots IAS; this will increase elevator effectivity. Retrim the stabilizer. Hold nose off runway, but avoid excessive nose high attitude. If possible, avoid the use of brakes while the nose is off the runway. If brakes are to be used, apply light braking and exercise extreme caution. *Do not use reverse thrust.*

Elevator effectiveness will deteriorate rapidly below 90 knots IAS; therefore, lower nose to runway before elevator control is lost (at approximately 100 knots IAS). Use rudder and differential main landing gear wheel braking for directional control after nose is on the runway. If runway length is limited, lower nose to runway as soon after touchdown as feasible. After nose is on the runway, use braking as required. At end of rollout, move fuel shutoff levers to OFF, pull all fire handles, and discharge fire extinguishing agent, if necessary.

## Both Main Gear Retracted; Nose Gear Extended



If the main landing gear cannot be extended, either normally or on free fall, a *main-gear-retracted-nose-gear-extended* landing can be made, since the inboard pods of Convair jet airliners have been designed to support the weight of the aircraft in the event of a controlled wheels-up landing on a hard surfaced runway.

Then, land with flaps, and bring airplane in as flat as possible. Make initial contact on aft fuselage; then allow nose gear to contact runway. The airplane should continue on the nose gear and aft fuselage. In this attitude, the inboard pods will be a foot or two off the ground. *If the nose gear touches down first, the airplane may porpoise.* At end of rollout, place fuel shutoff levers OFF, pull all fire handles, and discharge fire extinguishing agent, if necessary.

## Nose and One Main Gear Extended

If it is not possible to extend one main landing gear, it will be necessary to land in the *nose-and-one-main-gear-extended configuration.* Cross-feed or jettison fuel so that the wing with the main landing gear extended will be heavy, thus allowing a lower touchdown speed for the unsupported wing pods. Land normally. Immediately after touchdown, pull fire handles of engines on unsupported wing. At ground contact, slowly raise speedbrakes, to reduce landing roll while easing the pod gently to the runway surface. Use rudder and nose steering, with enough braking on the main gear and reverse thrust on the supported side to maintain directional control. Before wing has lost too much lift, ease it down until the outboard pod begins to drag; then apply heavy braking and reverse thrust on the supported side to bring the airplane to a stop. At end of rollout, move fuel shutoff levers to OFF, pull all fire handles, and discharge fire extinguishing agent, if necessary.

## One Main Gear Only Extended

If only one main gear can be extended, cross-feed or jettison fuel so that the wing with the landing gear extended will be heavy. This will provide adequate lateral control to a lower touchdown speed, and a less severe impact when pod makes contact with the runway.

Set wing flaps to full-down position, and make normal approach, landing flare, and touchdown.

Immediately after the one main gear touches down, pull fire handles of engines on unsupported wing.

To prevent pitching, lower nose gently to the runway while aerodynamic control is still available. *If engine pod is allowed to contact the runway first, the nose may be pitched down to the runway with excessive force.*

Extend speedbrakes for additional drag.

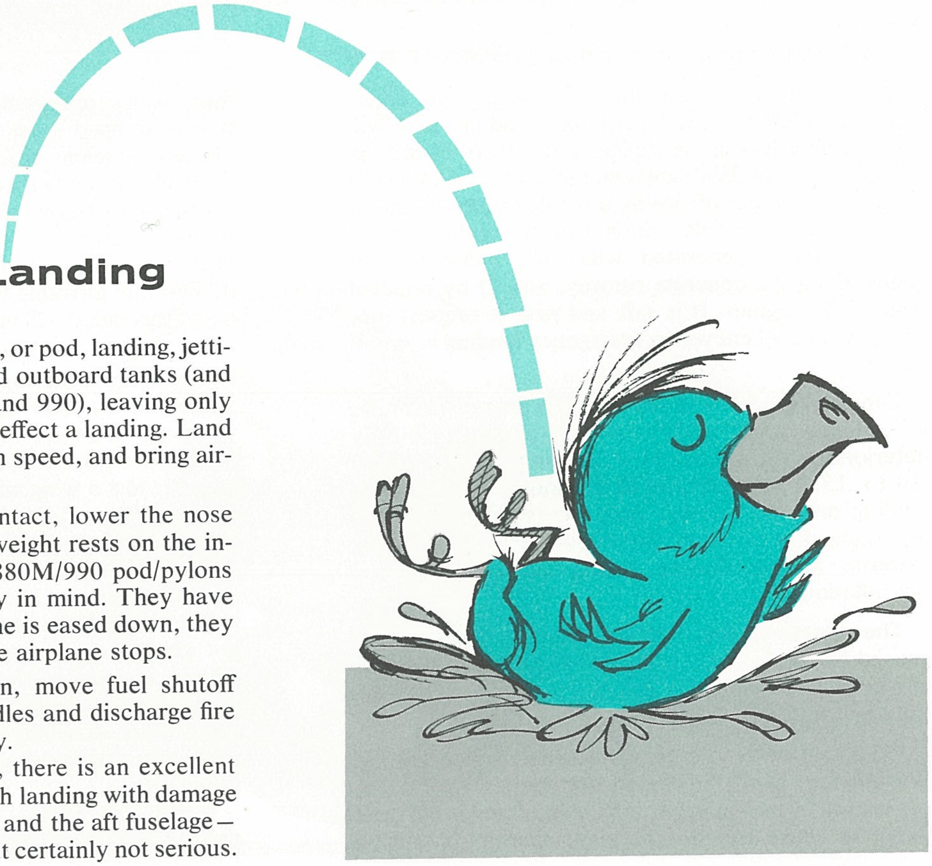
## Belly (or Pod) Landing

If it is necessary to make a belly, or pod, landing, jettison all fuel from the inboard and outboard tanks (and center section tanks on 880M and 990), leaving only enough in the outboard tanks to effect a landing. Land with full flaps for low touchdown speed, and bring airplane in as flat as possible.

When aft fuselage makes contact, lower the nose as gently as possible until the weight rests on the inboard pods. The Convair 880/880M/990 pod/pylons were built with this contingency in mind. They have extra strength and, if the airplane is eased down, they should carry the weight until the airplane stops.

Immediately after touchdown, move fuel shutoff levers to OFF, pull all fire handles and discharge fire extinguishing agent, if necessary.

With a good foamed runway, there is an excellent chance of making a fairly smooth landing with damage only to the pods, inboard flaps, and the aft fuselage—not exactly "minor" damage, but certainly not serious.



# FOAMING THE RUNWAY

LANDING ON A FOAMED RUNWAY during any emergency involving a malfunctioning landing gear will considerably lessen the danger and hazard of fire, on and after impact. With any emergency landing there is always the danger of fire as a result of the release of combustible materials which can be ignited by 1) friction sparks generated when the metal aircraft slides along the concrete runway, and 2) by residual heat in the engines. It is safe and wise to request runway foaming whenever an emergency landing is anticipated.

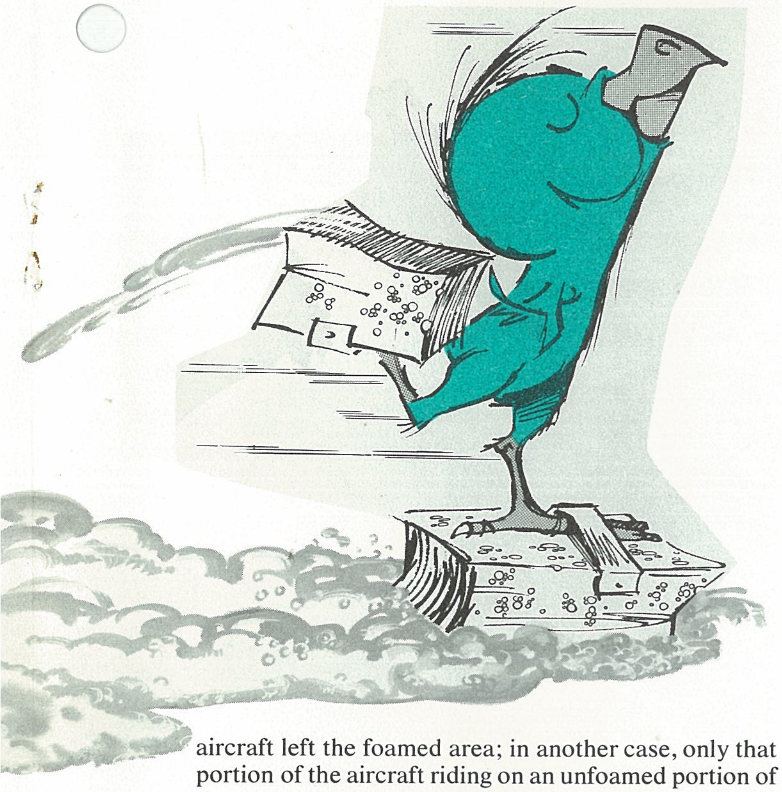
Landing on a foamed runway with gear up is similar to landing on a wet or slick runway—braking efficiency deteriorates, the coefficient of friction being reduced to .10 to .15. The coefficient of friction during a normal landing on a dry runway may vary between .25 and .30, depending on many variables—tire tread, runway material, air temperature, rolling speed of tires, and tire inflation.

The danger of fuel ignition from friction sparking caused by the fuselage sliding on the runway can usually be suppressed by the use of a foam blanket on the runway surface.

Tests made by the Naval Research Laboratory, Washington, D. C., indicated that metals vary in the generation of incendiary sparks. Aluminum is the least likely to cause friction sparking; sparking could be fairly well suppressed with steel and magnesium, when it was scraped along a runway surface, but, because of the coefficient of friction between titanium and the runway surface, a foam blanket had no effect in reducing the spark hazard generated by this material. Present transport aircraft utilize aluminum and steel in structural areas; by the time the supersonic transport, with its titanium airframe becomes a reality, friction sparking of this metal will probably be resolved.

The importance and merits of using foam in combating and preventing the spread of fire were demonstrated in an unrehearsed "Spectacular" about five years ago at a major airport. On takeoff, a four-engine transport with a fuel load of 5000 gallons of aviation gasoline lost a wing when it veered off the runway, and crashed into a jet with some 1700 gallons of JP-4 aboard. With the 2500 gallons of aviation gasoline from the severed wing, and approximately 1500 gallons of jet fuel spilled on the runway, crash fire crews were able to lay a foam rescue path to the entrance door of the piston-engine transport for successful egress of people trapped in that airplane. Another interesting fact in the use of foam in this incident, is that burning magnesium, dropping down from the aircraft, was immediately extinguished when it came in contact with the foam.

In another incident where the runway was foamed for an emergency landing, fire occurred only when the



aircraft left the foamed area; in another case, only that portion of the aircraft riding on an unfoamed portion of the runway experienced any fire.

A foam cover has a tendency to cool the metal as the airplane is being scraped along a runway during a gear-up landing, thus eliminating ignition from this source. Water alone would also have the advantage of cooling, but it needs a foam cover to hold it in place and to keep it from evaporating. The foam cover might be likened to a wet sponge. After a time, the top surface may begin to dry out, but the lower surface of the sponge remains wet for a long time.

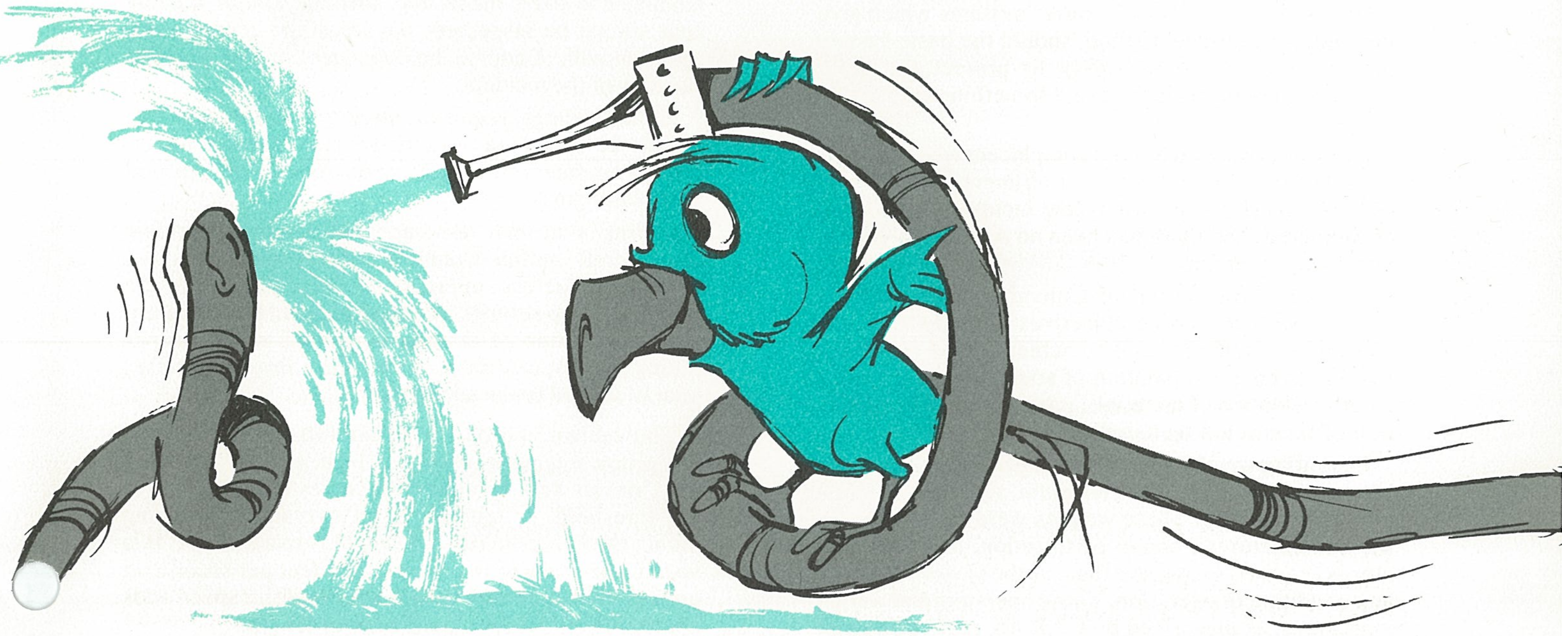
Foam is an aggregation of beads, or bubbles, of lower specific gravity than oil or water. It covers and clings to both vertical and horizontal surfaces; it cools hot surfaces and forms a fire-resistant blanket that resists breakdown by wind, flame, burning fuel, or contact with hot surfaces. It has the quality of resealing itself after most mechanical rupture, but the foam blanket can be disturbed by streams of water, or by dragging hose lines. The foam blanket holds the water on the runway in spite of the fact that it takes approximately one hour to foam a runway.

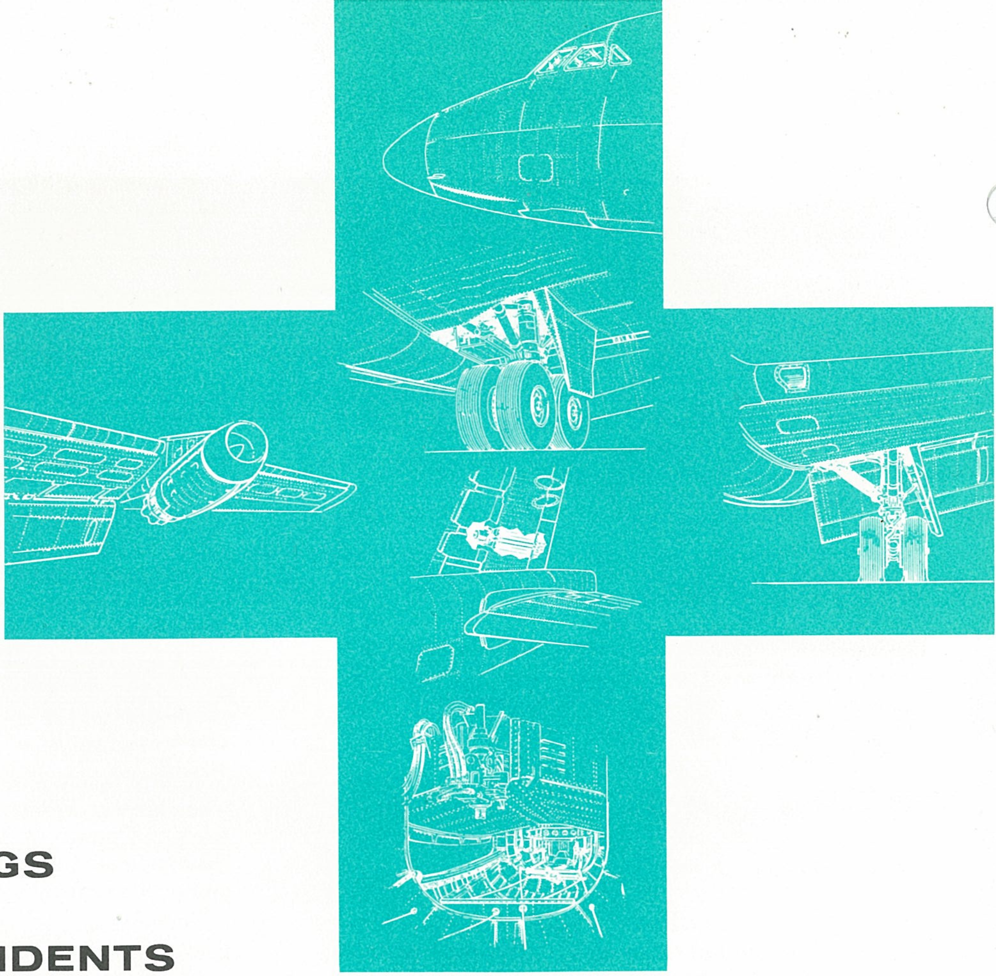
Foaming is recommended for any landing in which all three gears are not extended. A strip about 12 feet wide in the middle of the runway should be foamed when landing with the nose gear retracted. This strip will provide protection for the fuselage nose structure while keeping the runway relatively dry in the vicinity of the main landing gear wheels to permit main wheel braking. The foamed area should start at the approximate point where the pilot anticipates nose touchdown and extend to the far end of the runway.

A strip of foam about 120 feet wide should be laid when landing with both main landing gear retracted, or when making a pod landing. The strip should start at the anticipated touchdown point and extend to the far end of the runway.

Foaming may or may not be utilized, at the pilot's discretion, when landing with the nose gear and one main gear extended, or with only one main gear extended. Difficulty in predicting the skid path should be considered in making the decision to foam under these conditions; however, some benefit may be realized even if only the initial portion of the skid is through the foamed area.

National Fire Protection Association Bulletin 420-M contains pertinent information on theoretical benefits of foaming runways and on flight operational problems associated with foaming.





# STRUCTURAL INSPECTION AFTER HARD LANDINGS AND IN-FLIGHT INCIDENTS

WEBSTER DEFINES SAFETY as a condition of being safe; freedom from danger or hazard; devoid of whatever exposes one to danger or harm. This can be interpreted to mean that safety is a quality that must first be *provided* in order that the things that expose one to danger or harm can be *avoided*. In other words, safety must be built into an aircraft: *functional safety* so that the pilot will find it impossible, difficult, or complicated to do the wrong thing; *backup safety* systems which give the pilot an alternate method, should the basic system malfunction; *structural safety* to protect the flight crew and passengers in the event something unforeseen happens.

Convair is pleased but not complacent with the operating history of the Convair jet airliners. In four-and-one-half years of operation, few incidents have been encountered, and there has been no record of a fatality in passenger service.

The structural design of Convair aircraft was developed with the prime objectives of safety and serviceability. Methods used to achieve this dual objective involved a combination of sound design features, careful selection of materials, and resourceful application of fabrication techniques.

Operating weights established by structural analysis are considered to be the maximum, regardless of performance abilities. These weights were established by the manufacturer prior to certification, and the operator is required to observe them as the maximum under any condition of operation. These operating and weight limitations, as prescribed by CAR 4b, may seem strict and complex, but it must be agreed that the reasons behind them are in the best interests of flying safety.

Structurally, Convair jet airliners are designed to withstand hard landings, overweight landings, and flights through severe turbulence, without entailing major damage to the aircraft. However, if any of these incidents are experienced, or if an "available gear" landing has been made, the airframe and/or landing gear should be inspected; the areas and degree of inspection will, of course, be dependent on the type and severity of the incident.

Hard landings requiring structural inspection can usually be attributed to excessive rate of sink at touchdown, landing overweight, side loads, and ground winds and gusts.

During a normal approach and landing, stopping the aircraft within available runway depends on a number of factors: approach speed; height over the threshold: flap settings for recommended lift configuration; elimination of floating in ground effect; proper timing for speedbrake extension, thrust reverser operation, and brake application.

Touchdown speeds for jet aircraft are higher than for piston engine aircraft—as high as 140 knots for the Convair 880. If an aircraft comes in too high over the threshold, or touches down overspeed, stopping within the available runway length is marginal. At this speed, the airplane is traveling 236 feet per second on ground contact; every knot in excess of this speed adds approximately 27 feet to the runway length.

Under either of the foregoing conditions, if another factor is added—a wet, slick, or snow-covered runway—the situation is compounded. Under these conditions, there may not be enough runway left to make a normal stop; directional control may be impaired, the airplane may skid excessively.

In a controlled landing, however, the pilot can plan the let-down and landing during the approach phase. He can contact the tower at the destination airport to find out about weather and runway conditions. With this information, under most weather conditions—cross winds, wet and icy runways—he can land and stop within the landing distance requirements, without loss of directional control.

During any landing, reverse thrust and accelerated braking are significantly affected by crosswinds, although no special technique is required by the pilot. During the landing rollout, it may be necessary to decrease lateral control to a minimum in order to assure full directional control capability.

Add a slick runway to the crosswind factor, and braking efficiency is considerably reduced. However, with accountability of these two factors, plus pilot technique, a normal landing with maximum stopping capability and control can be utilized.

Extreme turbulence is rarely encountered; however, anytime the airplane is subjected to severe gust loadings in flight, a detailed inspection of the airframe should be considered, the extent of inspection depending on a description of the encounter by the flight crew. While hard and overweight landings occur more frequently, inspection of the immediate area of the landing gear and wing will indicate whether or not a more widespread inspection is indicated.

*What is a hard landing? What is extreme turbulence?* The pilot may find it somewhat difficult to precisely define and classify a severe operating condition. However, if there is any doubt about the severity of the experience, the airplane should be structurally inspected.

Charts in the Structural Repair Manual, Section 51-1, have been prepared to assist maintenance and structural personnel in inspection of the aircraft after any abnormal flight or landing incident. With this information, it should be possible for the operator to make an immediate evaluation—whether the aircraft requires repairs before another flight; whether the aircraft can be ferried to a repair base, if necessary, for the required repairs; or whether it can be returned to normal service.

## Inspection After Hard Landing

Inspection information is listed by area. No attempt has been made to list the areas of damage in the order in which damage may be expected to occur, since information on hard landings cannot be adequately substantiated by experience. It is anticipated, however, that if any damage were to occur as a result of loads exceeding the impact limits, it would appear first as skin buckles in the bottom of the fuselage, fore and aft of the main landing gear doors. From this point on, inspection of areas and a detailed inspection of components will depend on the severity and type of landing and stopping operation. Again, only *areas* of inspection are indicated—not the sequence in which they are expected to occur.

### FUSELAGE

1. *Fuselage Skin*—Inspect all areas of fuselage skin and plating for evidence of wrinkles, buckling, and loose or sheared rivets.

2. *Structure*—If excessive buckling is noted, inspect for warped or deformed structure, loose or sheared rivets and attaching bolts, and for any other indication of structural failure.

3. *Aft Pressure Bulkhead*—If there is evidence that the tail has contacted the ground, inspect bulkhead for cracks, distortion, flaking paint, and missing or pulled fasteners.

4. *Doors and Access Panels*—Visually inspect doors and panels for excessive clearances, misalignment, and distortion. Determine that latch on flare chute door is fully engaged (check through inspection holes in flare chute door).

### LANDING GEAR AND ATTACH FITTINGS

1. *Support Structure*—Inspect for loose or sheared fasteners and for any indications of overstress.

2. *Shock Strut*—Inspect for being excessively extended or compressed; check for leaks; check cylinder and piston for any cracks, and for indications of being bent.

3. *Doors and Fairings*—Check for cracks, pulled or missing fasteners, flaking paint, and for binding. Check actuating linkage for damage.

4. *Landing Gear Components*—Visually inspect the following items for cracks and distortion: pivot trunnion, drag and side braces, hydraulic actuating cylinder, wheels, torque arms, MLG truck assembly, forgings, welded parts, machined parts.

5. *Hydraulic Components*—Visually check for leaks.

6. If the airplane is on jacks, make operational check.

### WING

1. *Upper & Lower Wing Surfaces*—Inspect all areas of upper and lower surfaces for buckles, distortion, rivet condition, and any other indication of overstress. Some buckling may be evident on the wing surface in the area of the extended main landing gear.

2. *Wing-to-Fuselage Attachments*—Inspect attach fittings at front and rear spars for cracks, distortion, loose fasteners, and elongation of holes. Access to attach points is through wing-to-fuselage fillets and through main gear wheel wells.

3. *Fuel Tanks*—Inspect tank areas for any indication of leakage.

### POD/PYLON

1. *Pod/Pylon Skin Surfaces*—Inspect for wrinkles, distortion, and sheared or pulled fasteners.

2. *Pylon Plating and Formers*—Inspect for wrinkles, buckling, and loose or sheared rivets.

3. *Pylon Spars, Bulkheads, Attachment*—Inspect for cracks, distortion, and for any other indication of overstress. Inspect attaching area at wing front spar for plate buckling, wrinkles, and loose or sheared rivets. (Access to these areas may be gained by removing pylon leading edge and keel, and through applicable inspection plates.)

4. *Pod Cowling*—Inspect fit of pod cowling in relation to the pod fixed section and nose cowling. Any indication of shift between nacelle cowling in relation to pod fixed section or nose cowling may indicate a sprung or failed member and should be thoroughly investigated.

## Inspection After In-Flight Incidents

Inspections after flight through turbulence are similar to those required after a hard landing, and as described in the preceding paragraphs. Additionally, inspection of the control surfaces and control systems is required after flight through severe turbulence and after encounter with ground winds or gusts.

### CONTROL SURFACES AND FLIGHT CONTROLS

1. *Control Surfaces* — Inspect for condition, alignment, and distortion. Inspect hinges and attach points for security, cracks, and condition. Inspect attachment to push-pull rods and torque tubes for operation and freedom of movement by operating movable surfaces to their extreme range of travel and back to neutral.

2. *Flight Control System*—Inspect pulleys, brackets, bellcranks, and torque tubes for cracks, loose or sheared fasteners, distortion, and security. Inspect cables for proper tension. Any excess slack in cables indicates that a more thorough investigation of the control system is in order.

3. *Slats, Krueger Flaps, Spoilers* — Check for cracks, wrinkles, pulled or missing fasteners, flaking paint. Check attachment points.

### EMPENNAGE

1. *Skin Surfaces* — Inspect for buckles, distortion, and loose or sheared rivets.

2. *Fittings* — Inspect attach fittings and brackets for cracks and sheared fasteners.

3. *Stabilizer-to-Fuselage Fairings*—Inspect for cracks, distortion, and missing or pulled fasteners. If damage is evident, interior structure should be exposed for further examination.

After exceeding flap-down speeds, only the flaps, spoilers, slats, and their control systems require inspection. Check for buckles, cracks, and sheared rivets. Inspect trailing edge ribs that support flap actuator screwjack. Inspect attachment points of movable surfaces for binding and distortion.

After exceeding safe gear-down speeds, only the landing gear doors, fairings, and door mechanisms require inspection. These inspections are similar to those described in the applicable paragraphs preceding.

## CARE AND HANDLING OF TEFLON HOSE ASSEMBLIES

ONE OF THE MOST REMARKABLE of plastics is Teflon. Because it is chemically inert and thus immune to deterioration from contact with all fuels and synthetic base lubricants, it is being used extensively for gaskets, and backup rings for O-rings. Because it is also flexible, it is used in fluid systems of Convair jet airliners.

Teflon hose is formed from TFE (tetrafluorethylene resin), extruded into the desired tube size. The tube is then jacketed with helically wound stainless steel wire braid over the outside to provide strength and protection. The tubes thus fabricated withstand an operating pressure range of 1500 to 3000 psi, and resist high temperatures, corrosion, and fatigue.

In addition to being flexible, Teflon is tough, easily cleaned, and unaffected by virtually any foreign substance with which it might come in contact in an aircraft installation.

Although Teflon hose has excellent characteristics and meets specified requirements, it is not immune to damage. Compared with other lining materials, Teflon has limited capacity for taking sharp bending—it has a minimum radius only 3-1/2 times the diameter of the tube; therefore, it warrants special handling.

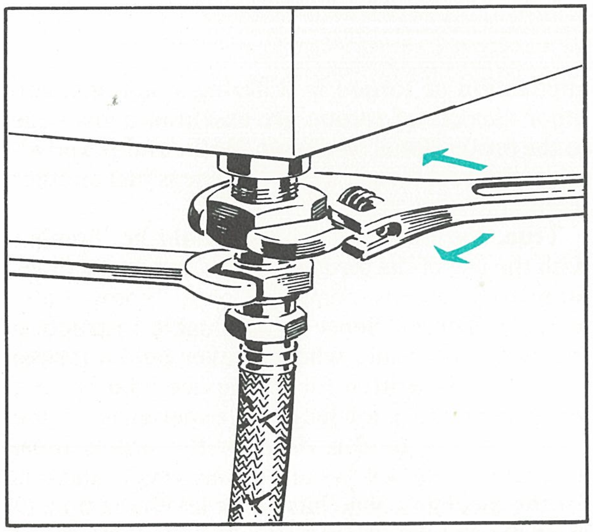
To maintain maximum serviceability and integrity of this flex hose, the manufacturers have established some guide lines in the proper handling and care of Teflon hose assemblies.

Manufacturers of the hose assemblies (Aeroquip and Resistoflex) specify minimum bend radii. In some installations, however, these bend radii have been exceeded; but in these particular hose assemblies, the hose has been carefully fabricated by the manufacturer under controlled conditions.

Most installations, nevertheless, have been designed with "gentle" bends, or the line bends are accomplished with elbows and certain other tube end fittings. Because of the limited bend radii of these hose assemblies, maintenance and shop personnel are cautioned not to reduce the prescribed bend to accomplish an installation.

Teflon hose, after a period in service, may take a degree of set, or become preformed to the installed position when subjected to high temperatures. It then becomes somewhat less capable of withstanding bending. Such a tube, or hose, may remain in service, but it can no longer tolerate the same amount of bending without damage. Since this condition is not readily apparent, it behooves maintenance personnel to handle all hose assemblies with care.

During installation and removal of hose assemblies, the tube shank hex should be held with a wrench, while a second wrench is used to loosen or tighten the attaching nut. This prevents the Teflon liner from being twisted. The possibility of damaging the Teflon liner is greater with the shorter hose lengths—there is less length to absorb the twisting action.



Tube assemblies, before installation, should be placed outside the work area to preclude the possibility of crushing. Dropping should be avoided, not only to prevent bending, but to preclude damage to the end fittings.

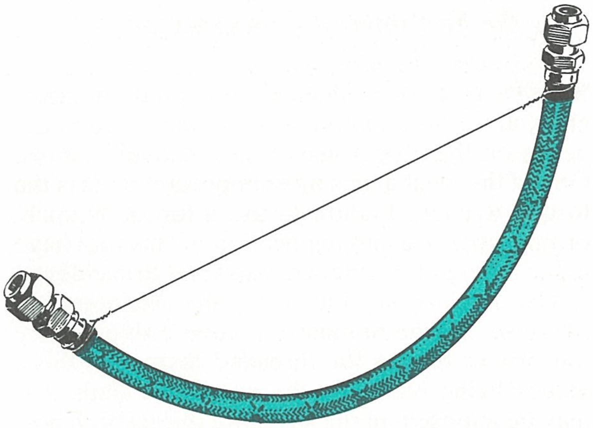
Tube assemblies with elbow and straight-through end fittings should be installed by attaching the elbow first. With swivel and straight-through ends, the swivel end should be attached first, but not torqued and secured until connection has been made and correct alignment established. Thus, it will not be necessary to twist the tube to obtain alignment with the elbow or swivel.

When installing and supporting flex hose assemblies, the hose should be bent in the same plane as the movement—not twisted or angled off—then clamped at the point where the hose changes planes. Hoses should be installed and clamped in such a manner that they cannot abrade on adjoining surfaces.

When disconnecting hose at one end to perform maintenance, it should be taped in place in its approximate position. *Do not bend it to get it out of the way.* When removing an accessory with hose attachment, the hose should be disconnected, because it cannot be properly supported while attached to the removed unit.

Tube assemblies—removed, or to be stored—should be left in the shape in which they were formed. *Do not attempt to straighten or bend a hose.* Bending or straightening a hose will tend to crimp the Teflon inner liner. A crimp or buckle changes the contour of the Teflon liner and may reduce flow through the line. To assure that hose assemblies are not inadvertently subjected to straightening or reverse bending, one expedient is to attach a piece of safety wire from one fitting to the other. This prevents the radius curve in the hose from straightening. For assemblies with one or more bends, or for long assemblies, the hoses may be simply taped to a light board.

All hoses should be inspected periodically for leakage, abrasion, and kinking. If leakage is at the fitting, fitting may be tightened (AN flared tube fittings only) and again inspected for leakage. *Do not retighten an Ermeto flareless tube fitting;* otherwise, damage to the tube with continued leakage will result. If Ermeto joint is leaking, back off nut and check tube for proper alignment; then retighten, but only to the original tightness.



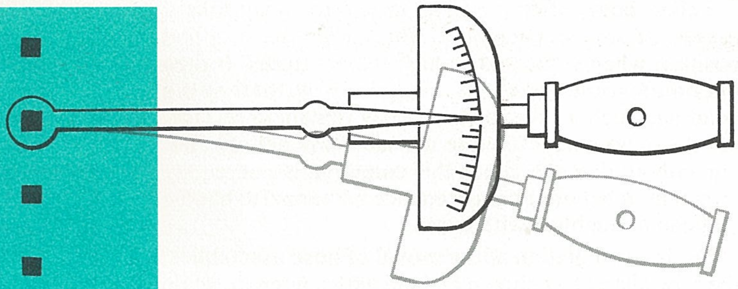
If leakage is in the hose, the hose is to be replaced. Random broken wires are acceptable. Where excessive wire breakage is found in a localized area—usually the result of abrasion—the hose line is to be replaced. If kinking is suspected, it is advisable to press the length of the hose with the hand to feel if the line underneath has been inadvertently twisted or kinked. Hose integrity can be further determined by passing a steel ball through the hose, following the hose ball size limits established by the vendor.

### Hose/Ball Size Limits

| Hose Size | Ball Size |
|---|---|
| -4 | 5/64 |
| -5 | 9/64 |
| -6 | 13/64 |
| -8 | 9/32 |
| -10 | 3/8 |
| -12 | 1/2 |
| -16 | 47/64 |
| -20 | 61/64 |

Observance of the foregoing limits and precautions in the handling and care of Teflon hose will reduce replacement rate and increase integrity of fluid systems.

6 40



# TORQUE SENSE

*An investment in knowledge*
*pays the best interest*— FRANKLIN

SAFETY IN FLIGHT depends on sound maintenance, and sound maintenance in many cases depends on the proper use of the mechanic's tools. One of the mechanic's most important tools is the torque wrench. Failure to use a torque wrench, or improper use and application of this tool have led to failure of component parts and to accidents.

The engineering blueprint, the Maintenance Manual, and the Standard Torque Table specify the proper torque for threaded fasteners, these values being based on the maximum loads that may be imposed on the structure during both normal flight maneuvers and excessive G loads—as in buffeting, etc.—and during the landing impact.

So that bolts will be capable of retaining the various assemblies when the aircraft is subjected to these loads, the high and low limits of the twist moment, or torque, used to tighten a nut, must be accurately controlled.

The importance of proper torquing is well stated in the Introduction to "Torque Sense," Convair's newest Programmed Instruction text.

"When an auto mechanic torques wrong, it's not too serious an error; his customers can at least walk to a garage. But, wrong torque from an A and E mechanic's wrench might be a different story. In many ways, improper torque is like a rattlesnake. Both do their dirty work from a twisted position; both are most deadly when they go undetected; and both generally strike when the victim is a long way from help."

The theory behind correct torque; the adapter formula; torque readings and what affects them; application of torque in differing situations; and other aspects of torque are essential knowledge to the professional mechanic. Without this knowledge, the best torque wrench made is just another wrench.

True, the mechanic is, or should be, familiar with the use of the torque wrench, but many times familiarity breeds contempt or a "know-it-all" attitude. Torque Sense is a valuable instruction for every mechanic who has ever held a torque wrench. It is written for the novice who has not yet gained the knowledge or experience of the "pro"; it is a good review for the professional mechanic who "knows all the answers"; and it is for the mechanic who has never taken the time to learn the theory of preload and the all-important adapter formula.

Application of the knowledge gained from this instruction will help contribute to sound maintenance and flight safety.

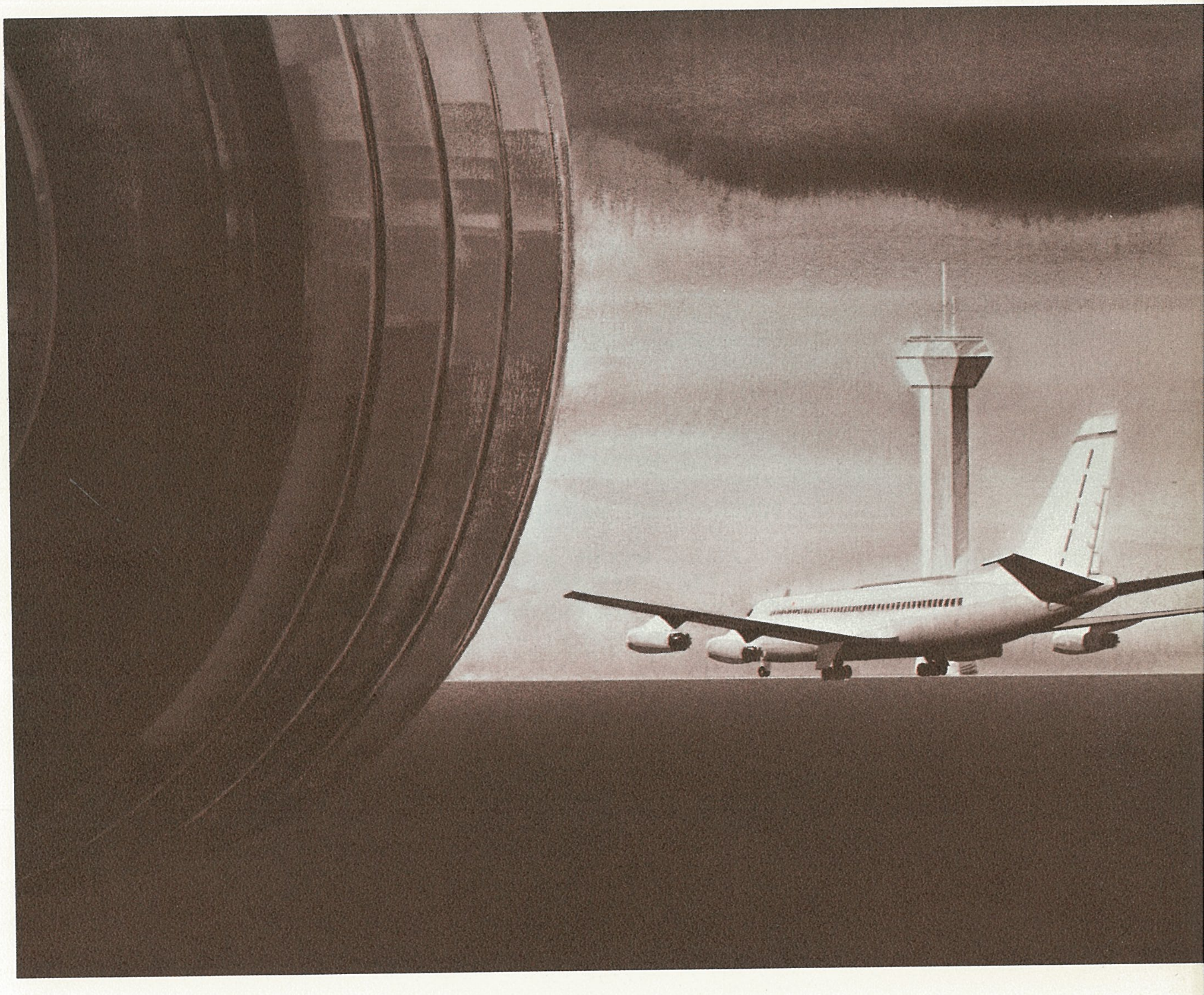
For more imformation on this valuable instruction, please contact

H. R. Kennedy
Mgr., Technical Publications
General Dynamics/Convair
P.O. Box 1950
San Diego, California 92112

**GENERAL DYNAMICS | CONVAIR**

VOLUME XVI NUMBER 4 NOVEMBER | DECEMBER 1964

# Convair Traveler



## In This Issue: The Importance of Aircraft Tire Maintenance

VOLUME XVI NUMBER 4 NOVEMBER|DECEMBER 1964

Convair Traveler

*In This Issue: The Importance of Aircraft Tire Maintenance*

OUR COVER

Aircraft tires are designed to carry high loads under high deflections for relatively short periods of time. By observing proper ground operations and following prescribed inspection and maintenance procedures, tire life can be increased. The artist–Geo. Paul.

# Convair Traveler

**VOLUME XVI NUMBER 4 NOVEMBER/DECEMBER 1964**

MANAGER, CUSTOMER SERVICE–**O. W. HARPER**
CHIEF ENGINEERING SERVICE–**L. J. BORDELON**
CHIEF, FIELD SERVICE–**R. E. SOMMERS**
MANAGER, SERVICE PARTS–**J. DOIG**
MANAGER, TECHNICAL PUBLICATIONS–
**H. R. KENNEDY**
EDITOR–**GERTRUDE S. HUNTER**

**IN THIS ISSUE**

**PAGE 3**

THE IMPORTANCE
OF
AIRCRAFT TIRE MAINTENANCE

**BACK COVER**

THE CHARGER...
Practical, Versatile, New Airplane

A digest of operation and service published monthly by the Technical Publications Section of GD|Convair, primarily for the interest of Convair operators. Permission to reprint any information from this periodical must be obtained from the Chief of Technical Publications, General Dynamics|Convair, San Diego 12, Calif. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without the specific approval of their cognizant organization.

**COPYRIGHT 1964**

**GENERAL DYNAMICS | CONVAIR**

# The Importance of Aircraft Tire Maintenance

TIRE PROBLEMS, generally associated with high-speed heavy gross-weight aircraft, are a critical factor in the safe operation of jet aircraft. Since these problems are generated on the ground rather than in the air, the seriousness of tire failures does not always receive the attention it deserves.

Aircraft tires are designed to cushion the shock of the landing impact; to provide the traction needed for slowing and stopping the aircraft; and to absorb roughness on the takeoff, landing, and taxi run. These operations subject the tires on today's transports to punishment that is rarely meted out to other components of the airplane. Contrary to common belief, it isn't the tremendous impact of the aircraft at high landing speeds that causes the greatest damage—it is the heat generated in the tire and wheel during the landing roll and taxiing. And, believe it or not, there are more tire failures on takeoff than during landing, probably because of heat generated in the tire and wheel during the long taxi run, braking, and turning, before the actual takeoff run, which also contributes to heating.

Heat buildup is generated within the body of the tire by flexing of the carcass, and also by the brakes which transfer heat through the wheels to the tires. The flexing action of a rolling tire creates heat which progressively builds up within the tire at a faster rate than the heat can be dissipated. Heat from tire flexing can cause tire deterioration and lead to premature failure.

A certain amount of deflection—which permits the tire to flatten somewhat—is desirable since it provides a larger bearing area to absorb shock loads, and to distribute heat evenly across the treads. As shown in figure 1, the tire is normal in shape at the sides and on top, and is flat where the tire rests on the ground. As the airplane rolls along the runway to a stop, the tire will flex as much as 4,000 times in less than a minute, the tire changing shape many times during each revolution.

This flexing causes friction, or molecular breakdown of the tire surface, and, of course, friction develops heat. Today's aircraft tires are designed to withstand friction for longer periods of time, but during long taxi runs or the landing roll, the buildup of friction-induced heat adversely affects tread wear and durability of the carcass.

As a protection against heat-induced blowouts,

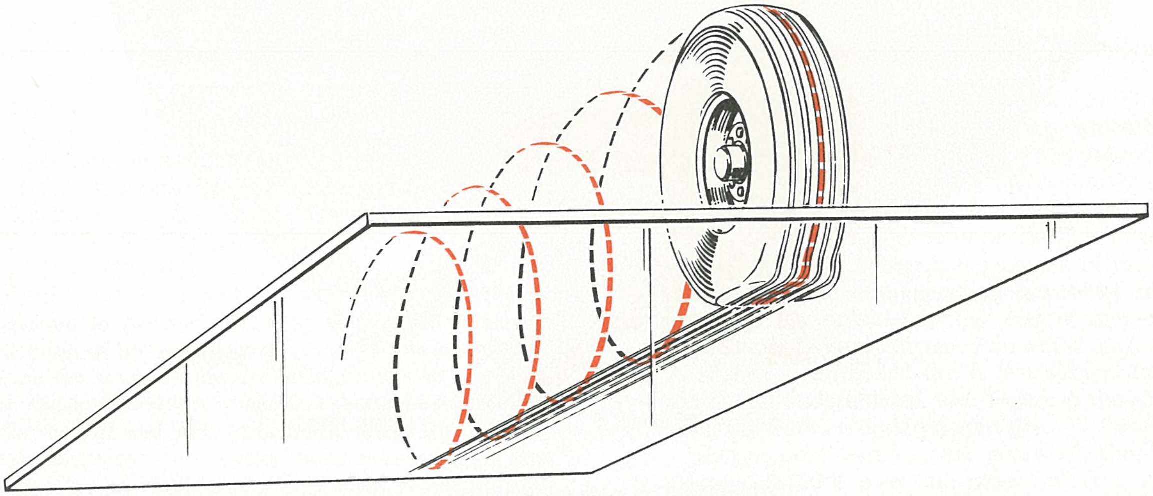


*Figure 1. Flexing action of tire.*

which could result in aircraft damage, the split wheels of Convair jet airliners incorporate fusible (blowout) plugs, designed to melt and blow out at a temperature of approximately 360°F, releasing tire pressures. A margin of safety in the tire prolongs the tire blowout point to a temperature beyond the melting point of the blowout plug.

Convair jet airliners utilize the Type VII and Type VIII high-speed tubeless tires. The Convair 880 and 880M use Type VII, 39 x 13, 22-ply tires on the main gear, and Type VII, 29 x 7.7, 12-ply on the nose gear; the 990 utilizes Type VIII, 41 x 15.0, 18-, 22- or 24-ply tires (depending on customer requirements) on the main gear, and Type VII, 29 x 7.7, 16-ply tires on the nose gear.

The tubeless tire is similar in construction and appearance to the conventional tire. When mounted, it can be identified only by the word "TUBELESS" on the sidewall. The tubeless tire is lighter in weight than the conventional tire and tube combination, and is simpler to maintain and easier to store.

An aircraft tubeless tire consists of four main parts; the tread and sidewall; the cord body, or casing; the inner liner; and the bead. These parts are further broken down and shown in the cutaway in figure 2.

The *Tread and Sidewall* is composed of a layer of rubber that covers the outer surface of the casing to protect the casing from cuts, bruises, and foreign particles and to provide an abrasive media for wear. The tread pattern, which varies depending on manufacturer and operational requirements, is sometimes laminated with nylon fabric, or is impregnated with low-gage chopped brass-plated steel wire. Operators who are using the reinforced treads are realizing considerable improvement in tire wear pattern. The reinforcing plies in the tread have the following advantages over tires with 100% rubber treads: 1) localized stresses are reduced because the load is spread over a wider tread area; 2) tread separation is reduced as a result of the reduced localized stresses; 3) greater tread depth is possible because fabric-reinforced tread is built up in layers, to reduce localized shear stresses under high dynamic conditions; 4) greater cut resistance is realized; 5) cracking of the tread groove is eliminated; 6) greater protection is provided for the carcass; 7) tires can be successfully retreaded

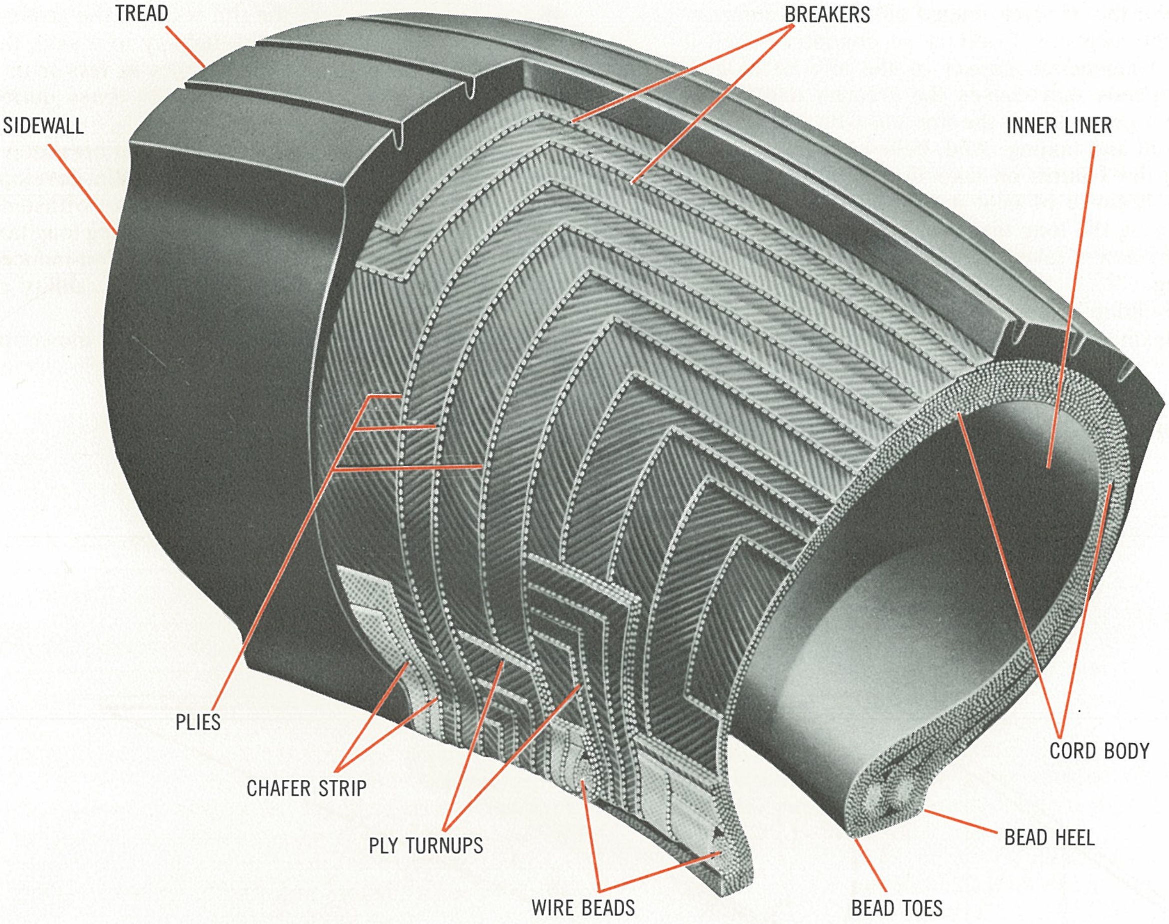


*Figure 2. Cross-section of tire.*

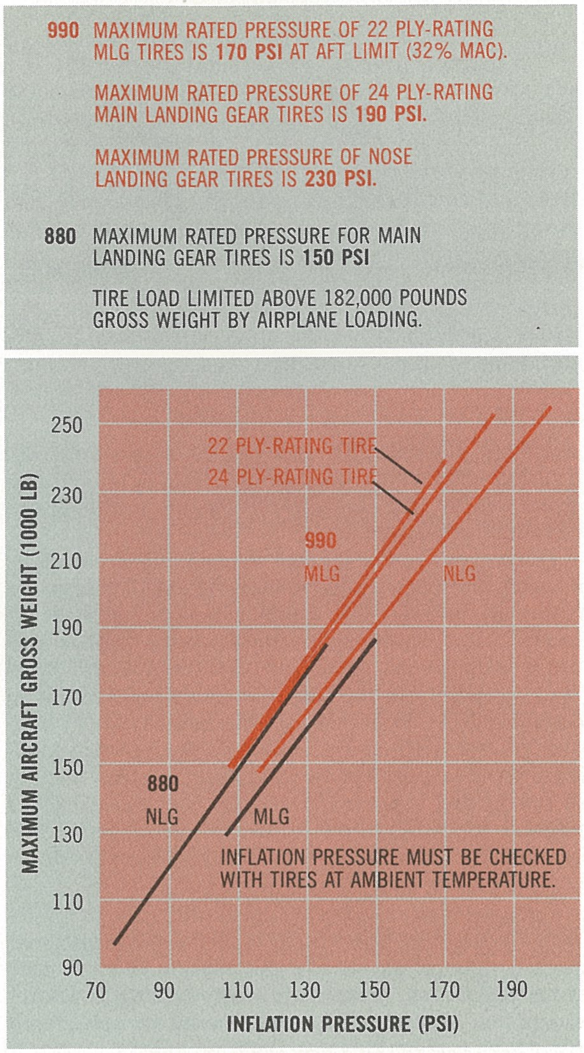
numerous times because of the protection built into the carcass.

The *Cord Body* is made up of plies of rubber-coated sheets of nylon cords. The ply compound of latex-resorcinal-formaldehyde insulates the individual cords and contributes to strength, flexibility, and heat resistance of the tire. The plies are assembled so that the cords run in different directions; this provides balanced tensile strength which maintains accurate tire contour. Some manufacturers utilize nylon fabric breakers between the tread and top ply. These breakers distribute shear stress under impact and landing shocks.

The load capacity of tires is determined by the ply rating system—not by the actual number of cord plies in the tire. In early tire production, when only cotton and rayon plies were used, the ply rating indicated the number of plies; today, the ply rating system, established by the Tire and Rim Association (TRA) is an index of tire strength and does not necessarily represent the number of plies in the tire. This is explained by the fact that a 20-ply nylon tire would have a higher load rating than a 20-ply cotton tire; thus, it is an index of tire casing strength and does not necessarily represent the number of cord plies in the casing.

An *Inner Liner*—a layer of rubber that is vulcanized to the first fabric layer of the cord body from bead to bead—serves the same purpose as an inner tube—to retain air.

The *Bead,* composed of fabric-wrapped steel wires imbedded in rubber, provides a base for the casing around which the plies are bonded. The tire is firmly held on the wheel by the bead and the bead wires. The number of wires in the bead depends on loading requirements of the tire design. Chafing strips on the outside of the beads protect the tire in the bead area from wheel chafing and give it additional strength and rigidity. They also protect the plies from possible damage during mounting or demounting operations.


**990** MAXIMUM RATED PRESSURE OF 22 PLY-RATING MLG TIRES IS **170 PSI** AT AFT LIMIT (32% MAC).

MAXIMUM RATED PRESSURE OF 24 PLY-RATING MAIN LANDING GEAR TIRES IS **190 PSI.**

MAXIMUM RATED PRESSURE OF NOSE LANDING GEAR TIRES IS **230 PSI.**

**880** MAXIMUM RATED PRESSURE FOR MAIN LANDING GEAR TIRES IS **150 PSI**

TIRE LOAD LIMITED ABOVE 182,000 POUNDS GROSS WEIGHT BY AIRPLANE LOADING.

INFLATION PRESSURE MUST BE CHECKED WITH TIRES AT AMBIENT TEMPERATURE.

*Figure 3. Tire inflation charts.*

## Inflation

Correct inflation is important to the life of the tire. For optimum tire performance, inflation pressure should be checked and adjusted once a day, preferably during preflight and when tires are cold. The B. F. Goodrich Company has prepared a Load vs Inflation chart to aid operators in determining and maintaining correct tire inflation pressures. See figure 3.

Optimum tire life can be obtained only if a 32% design deflection is maintained. This percent deflection allows full tread contact; however, when heat buildup could be a problem, this can voluntarily be sacrificed to preclude blowouts. To maintain design deflection of tire may require greater or lesser inflation within the scope of the tire rating; however, for inflation, the manufacturer's load data should be referenced.

Types VII and VIII tires are designed for optimum wear consistent with a reasonable non-injurious heat buildup at about 32% deflection. This, however, is not a rating for continuous duty, since heat causes an increase in tire pressure, which reduces the percentage of deflection.

Both underinflation and overinflation have an undesirable effect on tire life. See figure 4. Abnormal tread contact of the underinflated tire causes rapid wear on the outer edges of the tire (see figure 5). Underinflation subjects a tire to greater flexing, which builds up more heat and also breaks down the sidewall; it increases strain in the tread area, increasing the tendency toward ply or tread separation. Overinflation strains the tire; lowers resistance to bruising; increases skidding tendencies; subjects the center of the tread to excessive wear; and increases possibility of groove cracking. The reduced contact area of an overinflated tire reduces braking efficiency on wet or slick runways. A slightly overinflated tire is less subject to damage than is an underinflated tire. Figure 6 shows damage resulting from an underinflated tire.

During pilot training, tire pressures should be increased to 20% over the rated inflation, if landing frequency warrants it; but it should be kept in mind

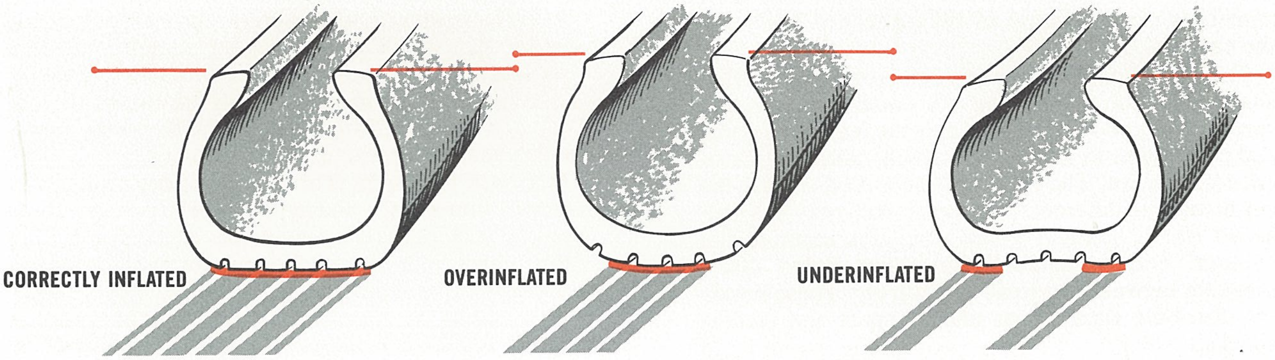


*Figure 4. Footprint area when tire is under load.*

that tires automatically become even more overinflated (for the weight condition) as fuel is burned and gross weight decreases, even though tire pressure remains the same.

During an aborted takeoff, when excessive braking is used, or when frequent takeoffs and landings are made, as during pilot training, brakes become extremely hot, transferring heat from the brakes into the wheels, to the tires. For pilot training with half-hour landing intervals, brakes and tires should be cooled at least 30 minutes for the 880/880M (45 minutes for the 990), and probably longer between landings. Gear may be left down in flight to effect cooling of brakes and tires; (12½ minutes for 880/880M, 15 minutes for 990); however, tire temperatures should be checked occasionally to ensure that the gear-down cooling time is adequate.

On scheduled revenue flights, landings are normally well-spaced, and turnaround time for passenger and baggage loading allows tire and brake cooling. Under these conditions, gear-down brake cooling is not required but is a necessity that should be considered since long taxi periods also build up heat.

Tires are designed for pressure increases that occur during normal operation. If tire pressure is checked and adjusted to the correct reading while the tire is hot, it will become underinflated as it cools and temperature returns to normal.

All tires leak a certain amount. If a tire has an inflation pressure loss of more than 5% in a 24-hour period, the reason should be determined. Because new tires have a tendency to grow a little, thereby reducing pressure, they should be rechecked 24 hours after installation.

In hot weather, tires should be inspected often, and pressures checked when tires are cold, so as to correct underinflation. Tires with damage that would be considered OK for one more flight under normal circumstances, should be removed if next scheduled takeoff is from a hot runway.

During rainy weather, tires should be inspected for cuts and tears; water has a tendency to lubricate cutting objects, and cuts and tears occur more frequently.

Complaints of air pressure loss are more common during cold weather; however, there are no seasonal limitations. Other causes of air loss are: 1) air temperature fluctuations and 2) inaccurate pressure gages. The latter is a frequent reason for "loss of pressure." Actually, it is not a loss of air pressure, but an inaccurate indication. Two gages may give a reading with a difference of as much as 25 pounds. That is why it is important to calibrate gages periodically. Inaccurate tire gages have been known to be in use where the gage read 10 pounds too high. This may have been 10 pounds too high at 80 pounds, which could very well be 25 pounds too high at 150 pounds pressure.

A certain amount of air loss from tubeless tires is a normal condition. Tubeless tires have vent holes which penetrate partially into the sidewalls to permit air, which has seeped through the inner liner, to escape before it results in separation of the carcass and/or tread. These vent holes are usually marked by a circle of green paint (figure 7). Leakage rate can be determined by applying soapy water over the vent. If leakage is normal, small bubbles, approximately ⅛ inch in diameter will form and break continuously over the bleed hole. If there is excessive leakage, large bubbles ⅜ inch or more in diameter will form and break rapidly over the hole. If excessive leakage is noted, tire is to be checked for air retention for approximately 24 hours by inflating the tire 10% above the normal inflation pressure. If pressure loss exceeds 4% of the elevated pressure within one hour, then the information is to be noted on the side of the tire and the tire removed from service. *Air pressure drop for tires in service should not exceed 5% in a 24-hour period.*

If it has been determined that air leakage is not at the vent holes, then the valve installation should be inspected.

Determine that valve cap is installed, that it is a VC-5 type, and that it is firmly screwed on. Cap not only prevents moisture and other foreign matter from entering the valve and damaging the core, but it helps to prevent leakage, should the valve core develop a leak.

Check valve core by the "bubble" method and, if a leak exists, replace core. Each time a tire is checked for inflation with a gage or is serviced with air, check the core. Only type C-4 cores are recommended for use on aircraft tires. These cores are designed for a temperature range of −65° to 400°F. C-4 cores are readily identified by copper plating and by a bar on the pin head.

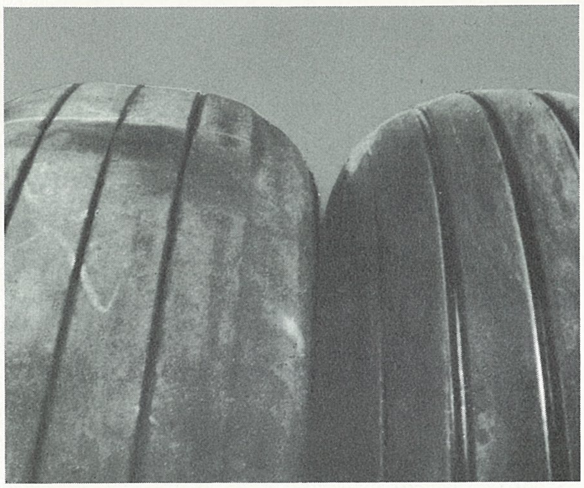


*Figure 5. Tire damage due to underinflation.*

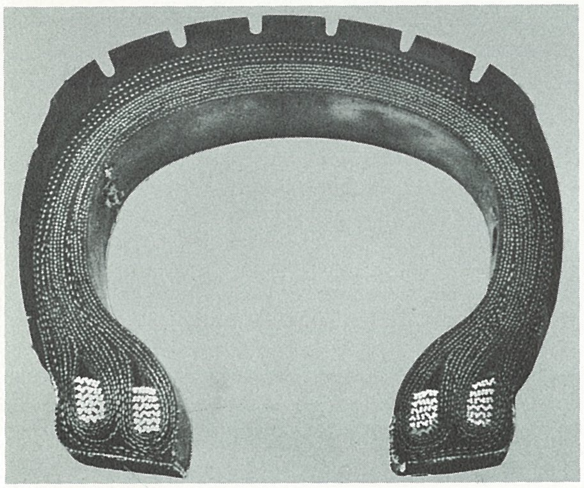


*Figure 6. Interior view of tire showing damage resulting from underinflation.*

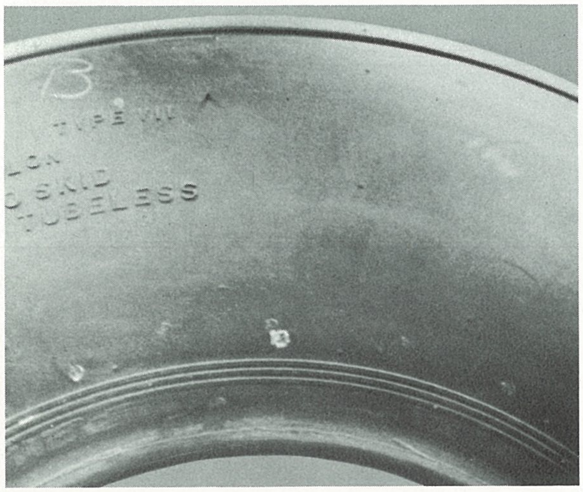


*Figure 7. Vent holes in sidewall.*

Check crown of tire for objects such as glass, nails, screws, etc., which could puncture the tire.

If leakage is "hidden," it will be necessary to remove the tire and wheel assembly to inspect the tire bead and the wheel (figure 8) for the following conditions which could lead to pressure loss.

- Check bead area. This is the primary sealing surface of a tubeless tire and any damage in this area could cause a leak. Check for evidence of damage by tire tools; check matching of tire and rim marks to determine in-service slippage.
- Check wheel for cracks or scratches in the flange area. Cracks are usually the result of fatigue failure; scratches and gouges result from improper mounting and demounting operations.
- Check for corrosion or wear in the bead ledge at the toe area of the tire bead. Check also for proper seating of the bead. Improper seating could be the result of dirt or accumulations of rubber from the tire.
- Check that valve stem and fusible plugs are properly sealed.
- Be sure valve hole and surrounding area are free of gouges, scratches, and foreign matter. Be sure proper grommet is used and that the valve is properly tightened.
- Determine that sealing surface of thermal fuse (blowout plug) is clean and free from scratches and dirt. Be sure O-ring is free of distortion and cuts.
- Check for proper seating of wheel halves. Foreign material or irregularities caused by improper handling could impair the sealing surface.
- Inspect O-ring to be sure it is properly installed—not twisted—and that it is properly lubricated with Dow Corning No. 4, or equivalent.
- Be sure wheel tie-bolts are properly lube-torqued to ensure compression of the O-ring under all temperature conditions.

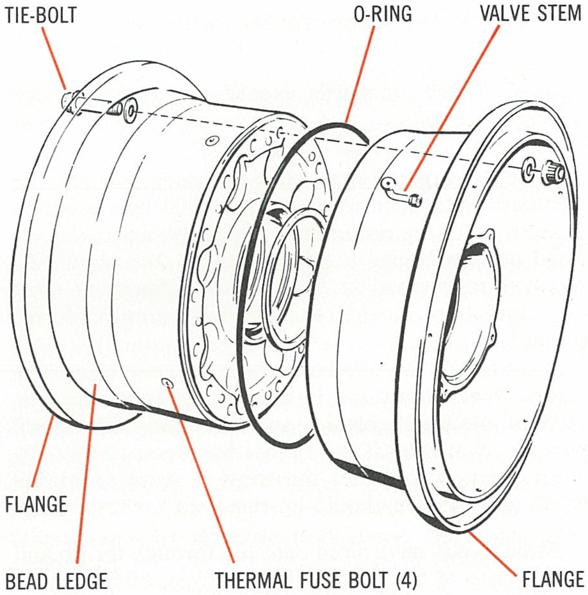


*Figure 8. Typical wheel assembly.*

## Tire Maintenance

It is important that the aircraft mechanic knows how to judge serviceability of a tire so that a tire can be removed from service before it becomes a potential hazard and, from an economical standpoint, that it is not removed when there are still several landings to go. By recognizing operating limits of a tire, properly observing tire inflation pressures, and by following good practices in tire installation and removal, tire failures can be virtually eliminated and service life improved.

Important also is that the proper replacement tire be used. The tire should be identified with the following data, which is indicated on the sidewall: size, type, ply rating, tubeless identity, and speed rating.

Standards for judging serviceability of tires have been established by the tire manufacturer and the retreader. These standards exceed the minimum safe operating conditions and leave enough of the carcass for effective retreading.

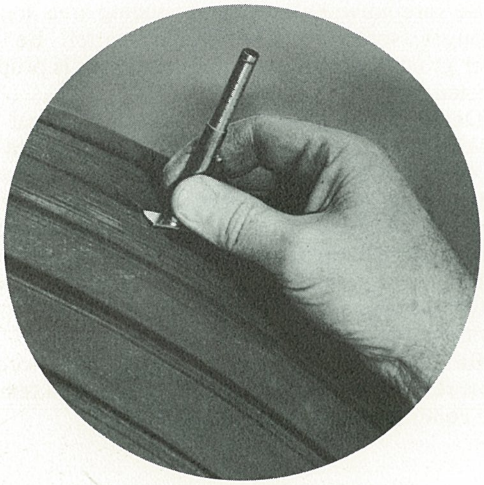


Figure 9. Depth gage for measuring tread wear.

A depth gage (figure 9) is designed to help the mechanic determine when the tread has been worn to a depth requiring retreading. Normally, when the tire tread pattern begins to disappear, the tire should be removed for retreading. Wear beyond this point, such as a skid burn, could render the tire unsuitable for retreading.

Some treads have tie-bars which are good wear indicators. When the tread is worn down to the tie bar, 20% of the tread remains and there are still several landings available; if the tie-bar has been completely worn away, it indicates the tread is worn to its full depth and the tire should be removed for retreading.

Some treads have a red cord ply through the rib and at the base of the groove. In this case, 80% wear is indicated when the red ply in the rib shows; when the red cord shows in the bottom of the groove, the tread is worn to its full depth and the tire should be removed for retreading.

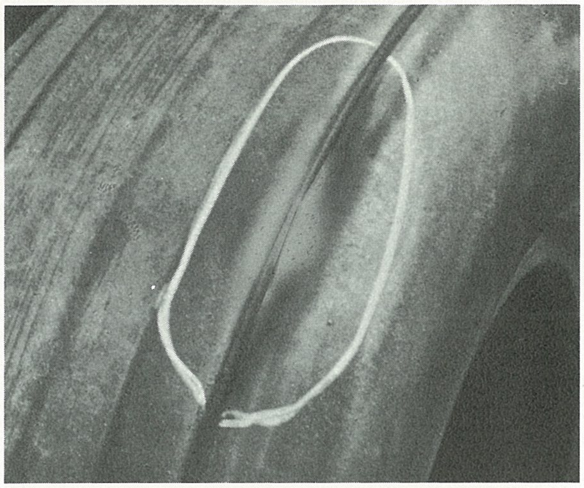


Figure 10. Bulge on tire; marked for removal.

If a tire is being removed because of cuts, blisters, abnormal wear, excessive heat, this information should be noted on the side of the tire and/or the damaged areas marked with a grease pencil before the tire is deflated and removed, because some of these areas may disappear or be hard to find after the tire is deflated. If inspection indicates that the tire is suitable for continued, but conditional, service, the information should be logged so that the tire may be inspected regularly and removed before the initial damage has progressed to a dangerous condition.

Tread cuts and wear are the major causes for removal of tires from service; therefore, it is recommended that the tread area be inspected first.

Cuts and tears in the tread area account for approximately 70% of the tires which are rejected as being unsuitable for retreading or repair. That is why a careful inspection of ramp areas and runways should

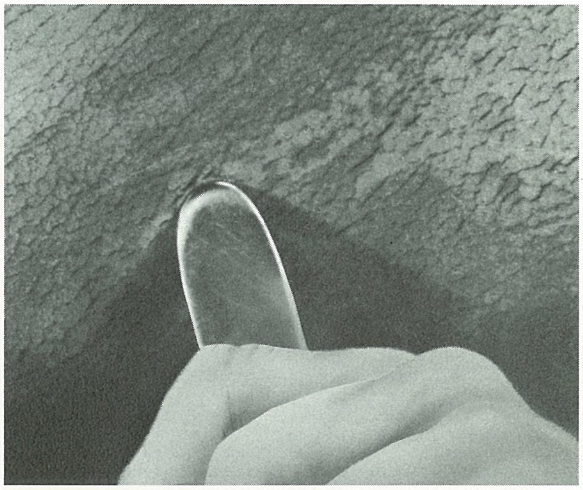


Figure 11. Ozone and weather checking.

be made regularly and all foreign objects picked up in the interest of extending service life of the casings as well as preventing in-service damage which could result in a tire failure. Magnetic cleaners pick up a large portion of these items but since stainless steel, glass, and rocks are not affected by magnets, a visual check should be made for sharp objects and these objects removed from the area before taxiing or towing the aircraft.

Following are limits established for conditional service, and for conditions under which a tire should be removed from service for a detailed inspection.

Check base of bead for foreign material, for exposed bead wires and cord, and for cuts, cracks and other defects and damage. If a bead wire is noted protruding from a tire, the condition may indicate a potential failure and the tire should be removed from service. Some operators, when finding a protruding bead wire, continue the tire in service to flight termination. If this is done, the bead wire should be cut off; the area encircled with a grease pencil; and the information noted in the log book so that the terminating station will remove the tire from service.

On the double wheel or double truck-mounted tires, a failed tire will shift the load to the other tire(s) on that axle or truck, and these tires may progressively deteriorate or fail as a result of overload and increased deflection. Even though failure is not apparent, consideration should be given to removal of the tire adjacent to the blown tire as soon as practicable.

During landing roll or taxi, if it is suspected that a tire has rolled over or made contact with a hard or sharp object, the tire should be visually inspected to determine if it is acceptable for continued service. If acceptable for further service, the information should be logged so that the tire can be checked at each turnaround since impact of this type can bruise the cord body, progressively weakening the tire.

If it is known that the tire has struck a large stone or damaging object, the tire should be removed from service. If cord damage and breaks are found, the tire should be scrapped. If there is no evidence of a break, the tire should be marked as having been subjected to a high impact load, and forwarded to the retreader for a more detailed inspection to establish serviceability.

"Climbing" a wheel chock can cause irreparable damage to a tire. Tires so damaged should be removed from service and the inside of the casing inspected for damage, thus precluding a blowout.

Although the nose wheel will swivel through 360° if the torque arms are disconnected, towing with the main wheels turned at angles greater than 50° is not recommended because this will result in scuffing of the main landing gear tires. Any time the main landing gear tires have been subjected to scuffing or scrubbing, the tire should be checked for damage to the cord body. This damage can usually be detected by a bulge or worn spot on the sidewall. Mark spot and remove tire from service. See figure 10.

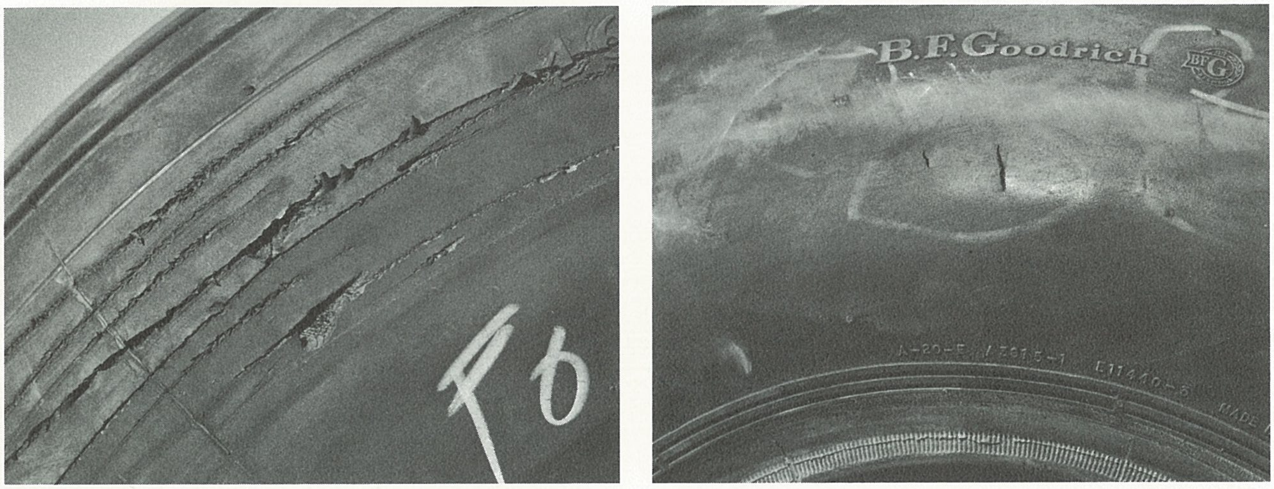


*Figure 12. Cuts in sidewall: OK for retread on right; beyond repair on left.*

Tires should be checked for bulges immediately after landing. Locating small bulges requires close examination. If the tires are checked while they are still warm, it will be easier to locate the bulges. If a bulge goes undetected, the tire may not fail in the next few landings, but a depression may result. This depression will subsequently lead to excessive wear in the depressed area.

A blister or bulge in the tread area can be determined by tapping the tread with a mallet. A bulged area will have a hollow sound. Mark the area with tire chalk, write the word "bulge," and remove the tire from service. Marking bulged areas is important because when air pressure is released, the bulge may disappear.

Tires of different manufacturers or with different tread patterns may vary as much in circumference as a worn and new tire of the same brand. When replacing

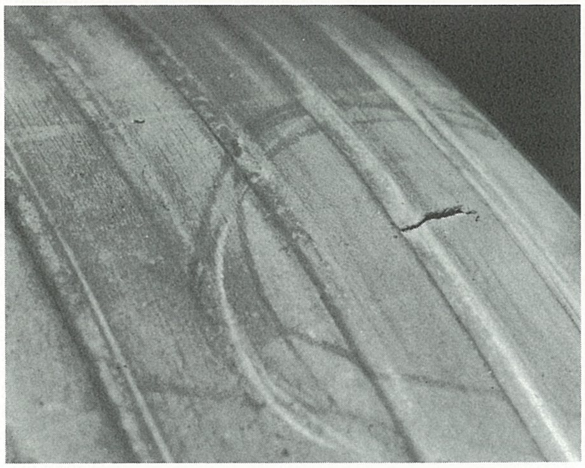


*Figure 13. If cut in tread exposes cord body, remove tire from service.*

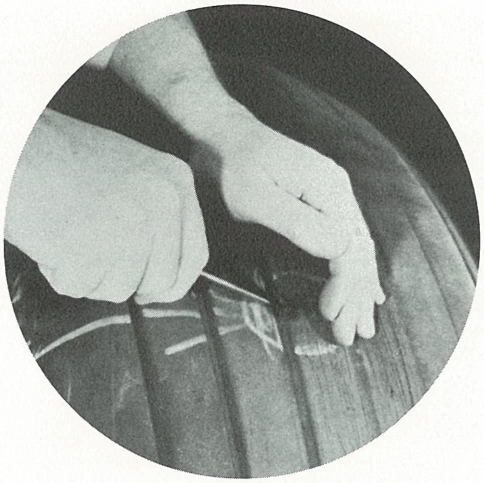


*Figure 14. Protect face when removing embedded object from tire.*

a nose landing gear tire, try to match tires within .75 inch. Mismatched tires result in excessive wear of the larger tire and will adversely affect directional control during nose wheel steering. This will require compensation by the pilot since the aircraft will turn in the direction of the smaller tire.

When replacing a main landing gear tire, a tire of the same brand, or tread pattern, should be used to ensure good braking performance and extended service life. In unmatched landing gear tires, the larger tire supports the weight of the smaller tire on that axle and the smaller tire becomes skid-burned and damaged by excessive wear during braking.

Scrap tires if weather-checking, ozone-checking, and cracking extend to the cord. Weather-checking is a normal condition that affects all tires but, unless the cords are exposed, the tire is suitable for continued service (see figure 11).

Tires with cuts in the sidewall which extend to and damage the outer ply should be scrapped (see figure 12).

A cut in the tread should be probed to determine if it extends into the cord body. Tire should be removed from service if cut exposes the cord (figure 13).

When probing for an embedded object in a cut, be sure the area is well shielded so that the object will not fly out and strike the inspector (see figure 14). Be careful not to enlarge the cut. Determine depth and width of injury; if injury penetrates the cord body, remove the tire for repair, retreading, or scrapping, depending on extent of damage. If the cut or hole does not expose the cord body, it is not necessary to take the tire out of service, but the area should be inspected periodically for extension of the cut or for embedded objects.

If a tire has a flat spot or skid burn that does not expose the cord body, the tire may remain in service; however, if the flat spot results in an unbalance severe enough to be noted by the pilot, the tire should be removed. An unbalance condition could also cause severe vibration with complete destruction of the tire.

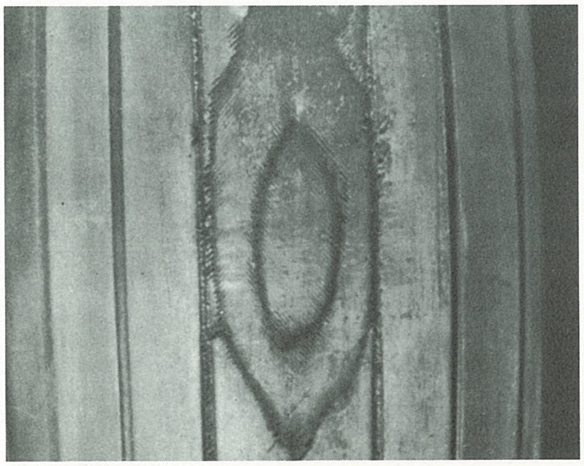


*Figure 15. Skid burn that exposes cord body.*

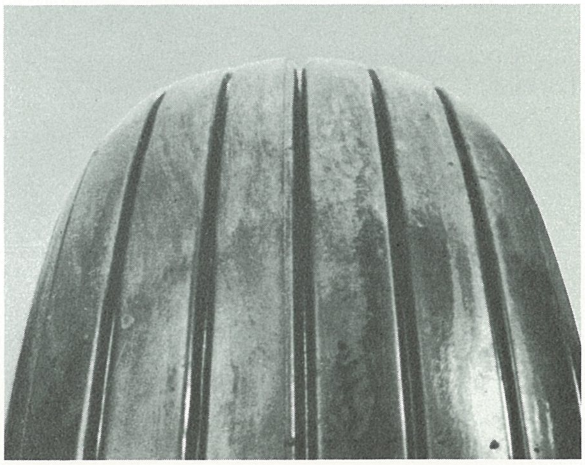


*Figure 16. Oil that contacts tire should be wiped off immediately.*

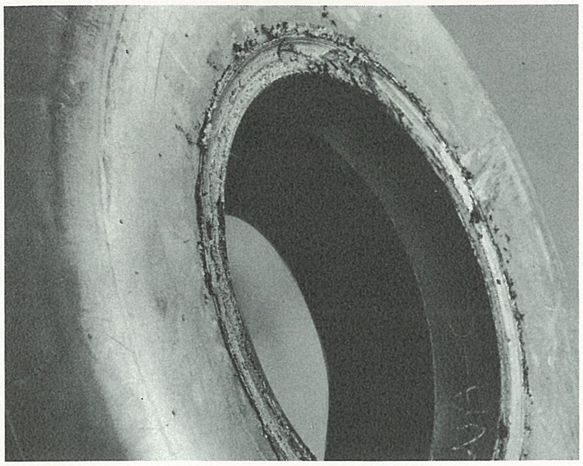


*Figure 17. Rim edge of tire damaged by excessive sloughing off of material.*

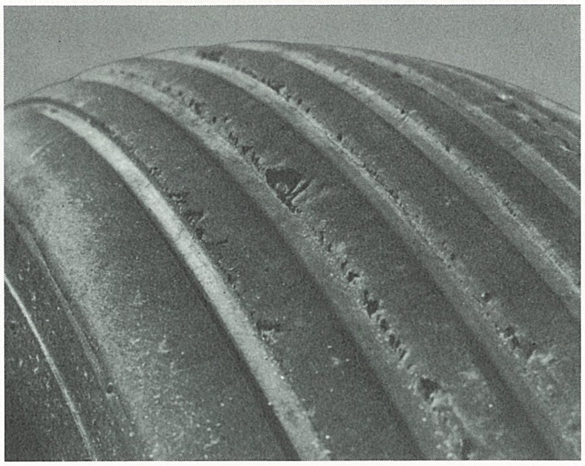


*Figure 18. Indication of loosening of tread ribs.*

If the flat spots expose the cord body, the tire should be removed (see figure 15). Flat spots are usually the result of a malfunctioning anti-skid and/or brake system, or wheel spin-up during landing. Improper mating of dual tires or improper inflation of the tires could cause burns on one of the tires.

Oil-soaked tires should be removed from service since oil deteriorates natural and synthetic rubbers (see figure 16). Whenever a tire comes in contact with oil, the oil should be wiped off immediately to preclude premature failure. Rubber that is oil-soaked will be tacky or spongy to the touch.

If excessive material is noted sloughing off the rim flange (see figure 17), the tire should be removed from service. This sloughing off of material is usually caused by excessive wheel heat.

If tread ribs appear to be coming loose, or if there are cracks or cuts at the base of the rib, the tire should be removed from service since the tread may be separating from the carcass (see figure 18).

If a cracking condition is found at the base of the groove, it should be probed to determine degree of penetration. Groove cracking is normally caused by insufficient under tread, tread compound deficiency, improper material for vulcanization, improper vulcanization, excessive ozone exposure, or overinflation. In the full circumferential rib-design treads of fabric construction, the outermost layer of fabric has a tendency to pull through the rubber stock in the bottom of the continuous groove. The impression or void left by the cord which has been pulled away from the rubber is susceptible to cracking and uninterrupted growth.

Considerable damage to tires can result from improper ground operations. Figure 19 shows tire damage resulting from sharp turns at high taxi speeds. This tire is suitable for continued service.

Figure 20 shows damage to sidewall as a result of dropping off edge of paved runway surface. This tire is OK for retreading if the damage does not penetrate to the cord body.

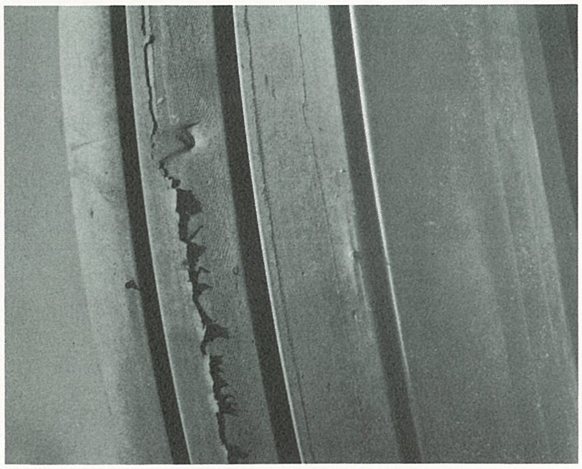


*Figure 19. Scrub damage resulting from improper ground operation.*

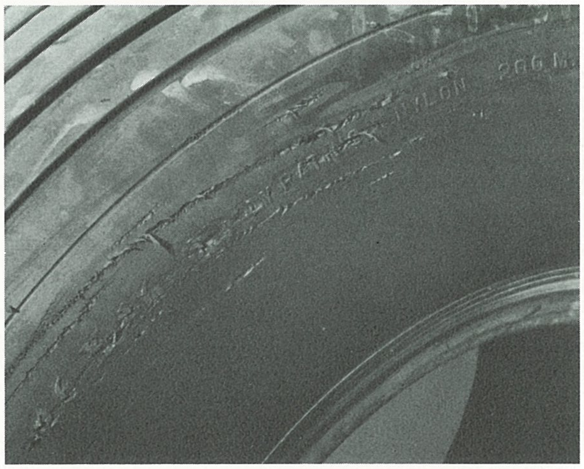


*Figure 20. Sidewall damage from dropping off edge of runway.*

# How to Improve Tire Life

Many tire failures can be eliminated if proper consideration is given to operation of the aircraft under certain ground operations; due consideration is given to condition of the runway and taxi areas; correct mounting and demounting procedures are observed; and a record is kept of all tire removals including scrap analysis. These factors are in addition to proper inspection and inflation of the tires given on the preceding pages.

### *Ground and Flight Operations*

Under normal conditions, with proper control, tires are able to withstand takeoff and landing stresses without damage. The following procedures should be followed by flight crews to minimize tire damage and premature failures.

When taxiing to the takeoff position, do not exceed 25 mph so as to minimize heat buildup in the tire. Use brake sparingly.

During taxi, be careful not to let one of the wheels drop off the paved edge of the runway. This could subject the tire to a damaging impact, and sidewall and shoulder may become severely bruised.

Make wide radius turns to avoid scrubbing the tires. Scrubbing, or scuffing, besides removing tread on the outer periphery of the tire, weakens the sidewall and bead of the tire.

During training flights, when touch-and-go landings are made, leave the landing gear extended for cooling of the tire and wheel assembly. In addition, establish flight time limits between each such landing. Some tire manufacturers recommend inspecting the tires after each series of five touch-and-go landings. Tires subjected to such landings should be thoroughly inspected for damage by a competent tire inspector.

During an aborted takeoff, a tire is subjected to extreme heat, developed during the braking and subsequent taxiing. Heat-incited damage cannot be detected by visual inspection; so it is recommended that the tires be removed and examined by a competent tire inspector. There have been aborted takeoffs in which the heat developed was not sufficient to affect the tire adversely; however, the temperature was high enough to melt the outer periphery of the thermal fuse plug, resulting in high air loss. The excessive deflection resulting from air loss could cause the tire to blow out on a subsequent takeoff.

More tires fail on takeoff than on landing; and too, tire failure is more dangerous on takeoff than on landing. A careful preflight inspection will minimize tire-induced incidents. At preflight, check for cuts and any type of damage or irregular wear. Remove foreign objects from tread. Tire inspection is not complete until aircraft is rolled so that the total tire can be examined.

### *Condition of Landing Field*

Tire damage is almost sure to result if taxiways, ramps, and runways are poorly maintained. Because sharp objects contacting tires cause most tire damage, these areas should be swept clean of such debris, and tires should be inspected often for external damage. Cuts, breaks, bruises, loose tread, and air blisters are conditions to look for.

Many damaging objects on the runway cannot be picked up by magnetic cleaners. Stainless steel, glass,

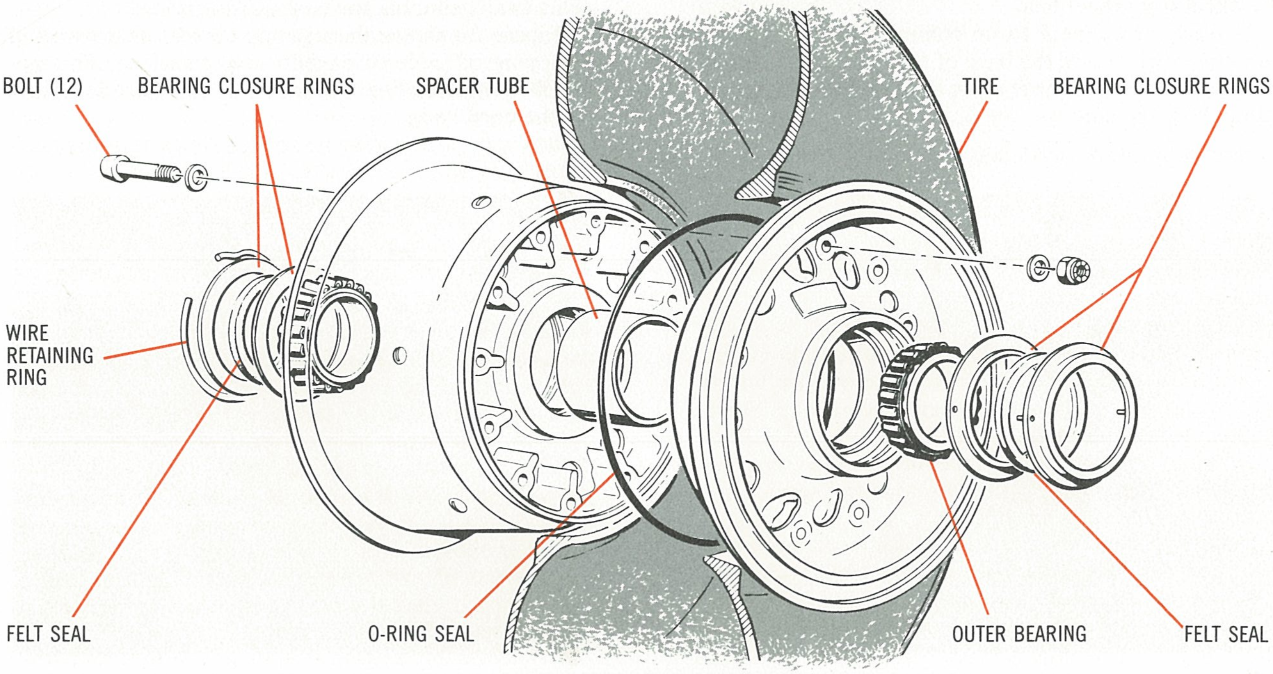


*Figure 21. Cross-section of wheel and tire (typical).*

gravel, and aluminum are not affected by magnets; therefore, it is up to maintenance personnel to keep these areas clean. Before moving an aircraft, it should be ascertained that there are no damaging objects in the area which could puncture, cut, or bruise the tires.

Chuck holes and cracks in the pavement are also damaging to tires. These areas should be repaired immediately. In cold climates, paved areas should be inspected frequently because they have a tendency to crack during freezing temperatures.

Just a little care and a few precautions in the hangar and around the field will help to prevent both minor and serious tire damage.

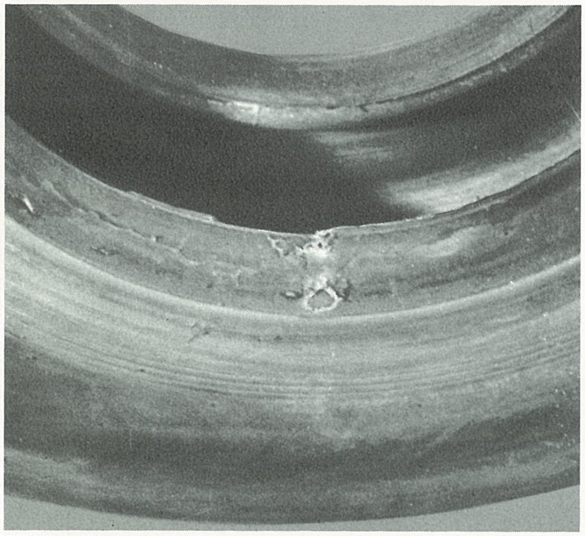


*Figure 22. Bead damage due to incorrect tire removal procedures.*

### *Correct Mounting and Demounting Procedures*

The number of aircraft incidents caused by wheels is far less than the number caused by tires. One wheel manufacturer has placed a service life of 8000 roll miles on Convair jet airliner wheels, there being an average of five roll-miles per exposure. An exposure in this instance consists of the landing and its attendant takeoff and ground handling.

Wheel failures usually occur during the taxi and takeoff phases, under high gross weight conditions and where side load is greatest. Most premature wheel failures are the result of improper maintenance. Some operators have increased their wheel service life 20% by using proper tools and procedures in the mounting and demounting of tires. Increasing wheel service life in turn increases tire service life.

Following are some general requirements that must be satisfied during demounting, disassembly, and installation of the wheel assembly to preclude damage to the wheel and subsequent damage to the tire (see figure 21).

- Use a heavy-duty tire bead breaking device incorporating a manually controlled hydraulic jack. Apply progressive force to the ring assembly when breaking tire beads loose from the wheel flange. Do not pry between flange and bead with sharp tools, or wheel and tire may be damaged, destroying sealing and structural qualities (see figure 22).
- Be sure wheels and tools are free from burrs, nicks, or other damage that could cause injury to tires.
- Before pulling wheel halves apart, chalk the half sections to identify their mating positions for subsequent assembly. Be sure to match these marks when reassembling wheel.
- Check wheel half attach bolts and nuts for damaged threads, etc.
- Remove wheel seal carefully and place on a clean surface; clean seal mating surfaces with a cloth dampened with denatured alcohol; replace if damaged or excessively deformed.
- Do not use wheel assembly that is badly corroded, or where the bead flange is worn excessively or damaged. Check bead flange area for scratches, nicks, or other damage that could cause tire failure.
- Remove dirt and accumulations of rubber from bead ledge so as to provide proper seating for the tire bead.
- Check condition of thermal fuses. Be sure sealing surface is clean and free from scratches and dirt, and that the sealing gasket is in good condition and properly installed. If air is lost as a result of melting of fuse plugs, the tire should be scrapped; however, an effort should be made to determine if plug melted at a lower temperature than that specified, or if air was lost because of improperly installed plug.
- Replace bent or distorted bearing closure rings and damaged cones and cups, and check that bearing cups are tightly seated. Wash bearing cones and cups with dry cleaning solvent, being careful to remove all old grease from the cone rollers.
- Before mounting tire, lubricate wheel seal with a light coat of Dow Corning No. 4, or equivalent, and install wheel seal on wheel half. The seal must be equalized on wheel and not twisted. If seal is re-used, it should be installed as near as possible in its original position. Install, but do not torque wheel bolts.
- With tire mounted and balance marks on tires and wheels matched, properly torque wheel bolts to assure adequate compression of the O-ring seal. Inflate tire just enough to seat beads. Bead seating pressures may vary considerably between tire manufacturers. In some instances, a pressure equal to the rated inflation may be required to seat the beads. After beads are seated, inflate tire to 100 psi for 24-hour leak check. Tire and wheel leakage should not exceed 5% of test pressure during the 24-hour leak check at room temperature. If new tire is being tested, a second 24-hour pressure leak check should be made. If pressure loss is greater than 5% during the second 24-hour period, the cause should be determined by using soap solution on all areas of tire, wheel, and valve. If leak test is satisfactory, inflate tire to proper value for storage or installation on aircraft, and install valve cap.
- When installing wheel and tire assembly on airplane, be sure tire is not inflated in excess of handling and storage pressure (30 psi).

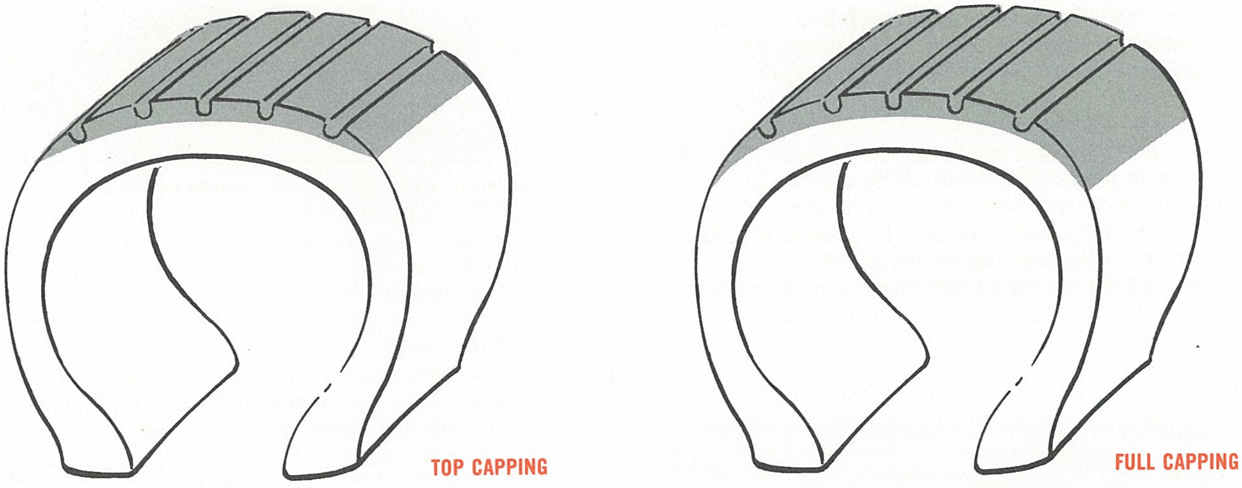


*Figure 23. Types of retreading/recapping.*

## Repairing and Retreading

All tires for scheduled airline operation must be manufactured and retreaded in accordance with TSO #62. Retreaded tires often give better service than the original tire. Condition of the carcass determines whether or not a tire can be retreaded and this determination is generally at the discretion of the recapper. One Convair 880 operator averages six recaps for the main gear tires and seven on the nose gear. The nose gear tire, after seven recaps, is used on their 340/440 fleet. The average number of landings per tire (new or recapped) is 75 for the main gear, and 35 for the nose gear.

Recapping is a general term meaning reconditioning of a tire by renewing the tread, or by renewing the tread plus one or both sidewalls. There are actually four different types of recapping for aircraft tires (see figure 23).

*Top Capping* is for tires worn to the bottom of the tread design, with no more than slight flat spotting and/or shoulder wear. The old tread is roughened and a new tread is applied.

*Full Capping* is for tires worn all around, for those flat-spotted on the cords, and those with numerous cuts in the tread area. The new tread area material is wider than that used on a top cap, and comes down over the shoulder of the tire.

*Three-quarter Retread* is for tires needing a new tread, plus renewal of the sidewall rubber on one side. A full cap is applied and approximately 1/16″ of the thickness of the old sidewall rubber is buffed off one side. New sidewall rubber is then applied over the bead to the edge of the new tread, on the buffed side only.

*Bead-to-Bead Retread* is a new tread and new sidewalls.

A regular schedule should be established for inspection of tires—at preflight, after a certain number of hours; after a certain number of retreads; and after a specified number of landings. A tire change record should be kept for each tire to assist the operator in establishing service life of tires and determining reason for unscheduled removals.

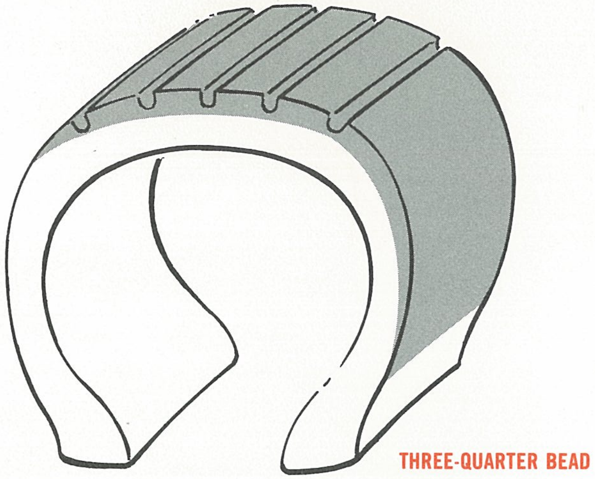
The tire history should be kept for the life of the tire. This record should include such information as Serial Number of tire; tire position; tire Manufacturer or Retreader; number of times retreaded; date of installation; date of removal; and reason for removal. Included in this record should be a scrap analysis. This record will assist the retreader in evaluation and the establishment of serviceability of the tire, and will assist the operator in taking proper corrective actions.

Each tire manufacturer and the retreader have established certain standards for judging tires—extent of wear, depth and length of cuts, and other visible deterioration of tires. Although these standards may vary somewhat between manufacturers, they are all far above the minimum safe operating conditions for that particular tire. This safety margin is designed to forestall the practice of completely wearing out tires, and ensuring a suitable carcass for successful retreading.

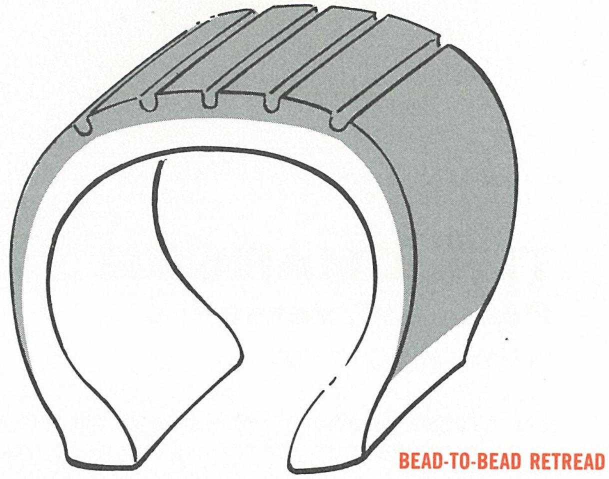
Some retreads incorporate a wire-barrier-reinforced tread. Placement of the wire in the tread may vary between manufacturers; however, experience to date indicates that this wire barrier provides increased resistance to cuts, prolonging casing life, increasing durability, and assuring retreadability.

The tire bead is the strongest part of the tire; the sidewall cord body is the weakest part. Injuries to the sidewall cord body usually render the tire unsuitable for retreading or repair. The tread portion of the tire has a relatively higher strength ratio than the rest of the tire, exclusive of the bead.

In normal operation, injuries resulting from contact with runway debris are almost wholly in the tread portion of the tire. The crown portion of the cord body, or that portion directly beneath the tread, is



THREE-QUARTER BEAD



BEAD-TO-BEAD RETREAD

also relatively high in strength, permitting repairs in the tread area.

Tires that become injured in service can be successfully repaired but the amount of service remaining in the tire is an important factor in the feasibility to repair or not to repair. The following recommendations are made:

- Any tire with at least 30% of tread life remaining normally is considered as having enough service life to warrant repair.
- Tread injuries that penetrate no more than 40% of the actual body plies (breaker strips and fabric reinforcement strips in the tread not included) and have a maximum surface length of 1½ inches with maximum width no more than ¼ inch may be repaired. After the old tread has been removed, cuts into the cord body are re-examined; the limit of acceptability is 1 inch in length and ⅛ inch in width at the surface.
- Injuries through the cord body in the tread area, measuring ⅛ inch or less at the largest point, are considered punctures and are easily repaired during the retreading process.
- Shallow cuts in the sidewall or shoulder rubber only are repairable if cords are exposed but not damaged.
- Tires having minor injuries through the finishing strip, or slight injuries caused by tire tools in the general bead area, are repairable if the injury does not extend into the plies of the tire, and provided there is no sign of separation in the bead area. If the finishing strips are loose or blistered, they can be replaced only by bead-to-bead retreading.
- Liner blisters smaller than 4″ × 8″ may be repaired if there are no more than two in any one quarter section of the tire, and no more than five in the complete tire. Normally, however, it would be more economical to do this work at the time the tire is recapped.

The following conditions disqualify a tire for repair.

- Any injury to the beads or in the bead area (except injuries limited to the bead cover or finishing strip).
- Any tire that shows evidence of ply or tread separation.
- Any tire with a protruding bead wire or badly kinked bead.
- Any tire with loose, damaged, or broken cords on the inside.
- Tires with broken or cut cords in the outside of the sidewall or shoulder area.
- Tires that have gone flat, or partially flat, due to the melting or failure of fuse plugs should normally be scrapped, even though there may be no visible evidence of damage to the inside or outside of the tire. The only exceptions would be where it was known that the fuse plug leaked air because of faulty installation or defective plug.

When it is considered economical, spot repairs can be made on cuts, snags, etc. in the tread, if they are no more than 25% through the actual body plies of the tire and not over two inches in length at the surface. Vulcanized spot repairs are also made at times to fill in tread gouges that do not go deeper than the tread rubber and do not penetrate the cord body.

In summary, aircraft tires must be carefully maintained to meet the rigorous demands of high-speed jet operations. The aircraft manufacturer and the tire manufacturer are as anxious as the operator to improve tire service life and thus are always available to advise and to make an experienced judgment regarding continued serviceability of a tire and advisability of retreading.

Convair gratefully extends thanks to the following organizations for their assistance in the preparation of this article:

The B. F. Goodrich Company
The Goodyear Tire & Rubber Company
Thompson Aircraft Tire Company

# THE CHARGER . . .

## Practical, versatile, new airplane

The Charger, commonly referred to as the COIN, made its maiden flight, 25 November, just 35 weeks after the start of design engineering at General Dynamics/Convair. The first flight lasted 38 minutes. It took off from San Diego's Lindbergh Field, flew along the coast between San Diego and the Mexican border, and landed, as planned, at nearby North Island Naval Air Station. After a brief stop, it took off for a 45-minute flight and landed back at Lindbergh Field.

Test Pilot John W. Knebel called the Charger "a very nimble airplane that was hard to hold back. It showed me a quick, clean response."

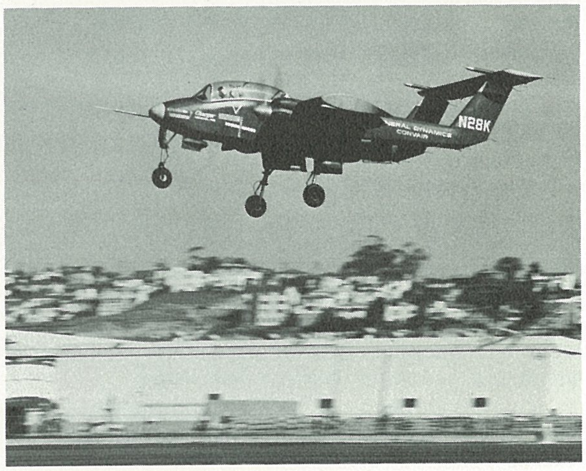
The Charger has twin booms extending aft from the engines to a twin vertical tail with a large horizontal stabilizer. It is powered by two Pratt & Whitney T-74, 650-horsepower turboprop engines, driving two nine-foot propellers. These engines are rated among the most reliable small engines now available. Their large power reserve and small light design make the Charger one of the safest airplanes for close-to-the-ground operation.

The engines can operate on truck fuels as well as on aviation fuels. Equipped with external fuel tanks, the military version has a ferry range of 2,600 nautical miles. Such a range can easily enable it to fly from California to Hawaii, for example, the longest overwater leg it would have to make for overseas deployment.

Extra large flaps extending almost the entire length of the wing trailing edge, provide maximum lift for short takeoffs and landings, allowing the aircraft to take off with a ground run of only 225 feet and to clear a 50-foot obstacle in less than 500 feet.

The Charger's ability to fly slowly at low altitudes makes it ideal for surveillance and reconnaissance missions. Loaded for a surveillance run, the Charger can take off from sod fields, fly 50 nautical miles, loiter for two hours with a 1,200-pound surveillance payload, and return to base.

The Charger is designed to provide close support to ground troops in a variety of tactical situations. Its high maneuverability and fire power make it particularly effective in destroying small enemy targets, escorting troop-carrying helicopters, and serving as an aerial command post to coordinate ground action and direct artillery fire.



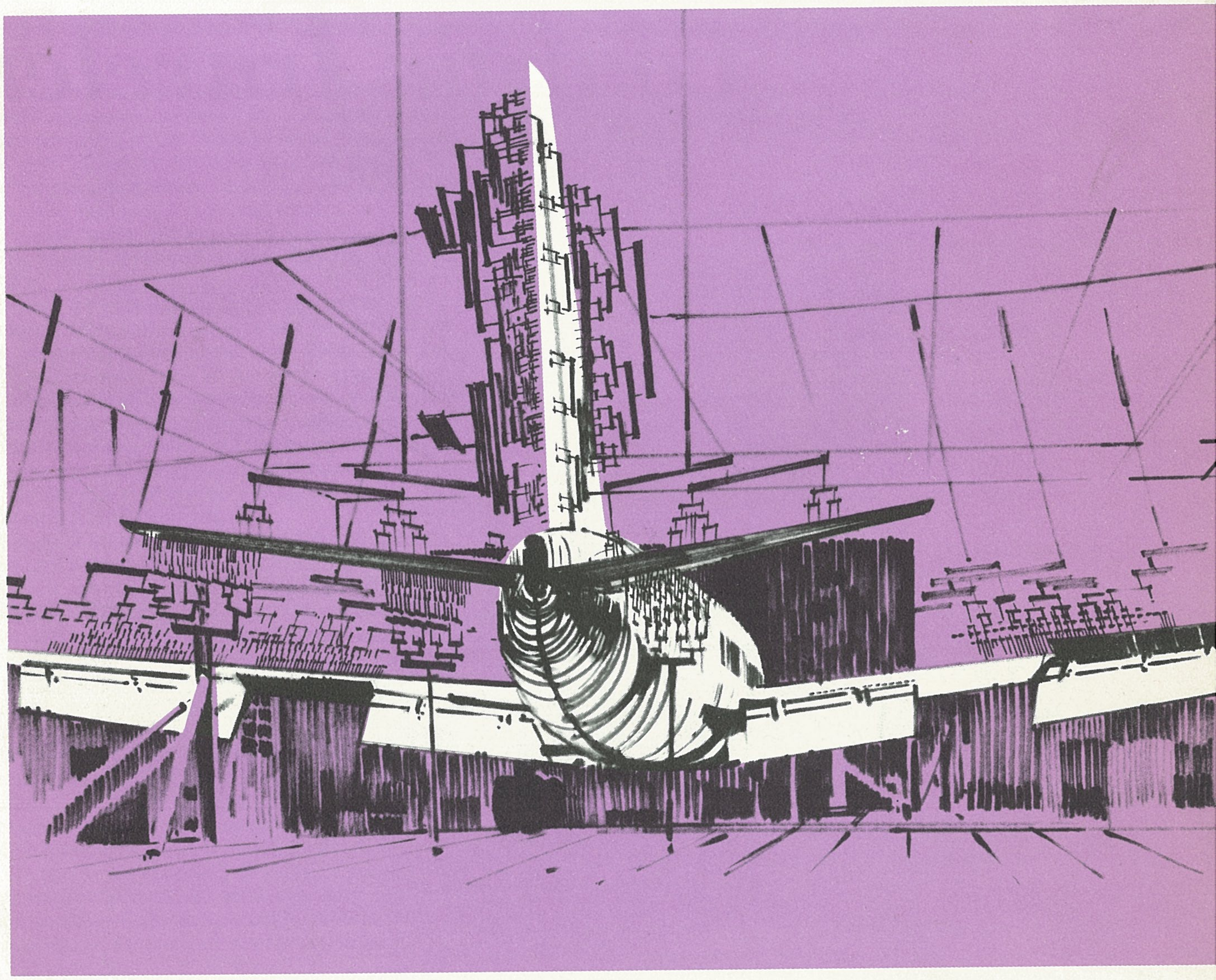
It can be used as a personnel transport; the airplane being capable of carrying six fully equipped paratroopers, or two litter patients and a medic. It can be used as a cargo carrier, airlifting up to 6,000 pounds of fuel, ammunition or other critical supplies; this is $1^1/_2$ times its own weight empty.

In addition to a 6,000-pound payload capability, the Charger has the alternate capability for operation from an aircraft carrier, unaided by catapults or arresting gear. With the installation of floats, it is suitable for operation as an amphibian.

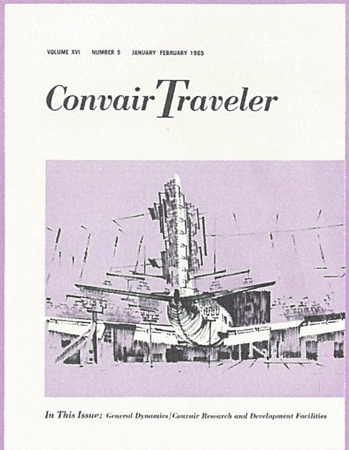
**GENERAL DYNAMICS | CONVAIR**

VOLUME XVI NUMBER 5 JANUARY | FEBRUARY 1965

# Convair Traveler



**In This Issue:** General Dynamics | Convair Research and Development Facilities


VOLUME XVI NUMBER 5 JANUARY FEBRUARY 1965

Convair Traveler

*In This Issue:* General Dynamics|Convair Research and Development Facilities

The Convair 880, before entering scheduled airline operation, was subjected to extensive testing. In one of these tests at GD/Convair's Research and Development Laboratories, tension pads were attached to the horizontal and vertical stabilizers. An arrangement of whiffletrees, connected to hydraulically actuated cylinders, pulled the surfaces, spreading the load over a large area to simulate stresses that were expected to be encountered in actual flight. From these and other tests, engineers were able to prove that the airplane structure met design deflection and strength requirements. According to George Paul, layout artist for this issue, "You can't see the forest for the whiffletrees."

# *Convair Traveler*

**VOLUME XVI NUMBER 5 JANUARY/FEBRUARY 1965**

MANAGER, CUSTOMER SERVICE—**O. W. HARPER**
CHIEF ENGINEERING SERVICE—**L. J. BORDELON**
CHIEF, FIELD SERVICE—**R. E. SOMMERS**
MANAGER, SERVICE PARTS—**J. DOIG**
MANAGER, TECHNICAL PUBLICATIONS—
**H. R. KENNEDY**
EDITOR—**GERTRUDE S. HUNTER**

**IN THIS ISSUE**

**PAGE 3**

GD/CONVAIR RESEARCH AND DEVELOPMENT FACILITIES

**BACK COVER**

CONVAIR DEVELOPS TELEMETERING BUOY SYSTEM

A digest of operation and service published monthly by the Technical Publications Section of GD|Convair, primarily for the interest of Convair operators. Permission to reprint any information from this periodical must be obtained from the Chief of Technical Publications, General Dynamics|Convair, San Diego 12, Calif. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without the specific approval of their cognizant organization.

**COPYRIGHT 1965**

# General Dynamics | Convair Research and Development Facilities

LABORATORY RESEARCH has become an increasingly complex operation because of the technological changes occurring in the fields of major interest, and in the many development programs anticipated. Scientific investigation today cannot be tightly isolated to categories such as space, air, electronics, and nuclear studies. And, under the impact of scientific advance, systems being developed today may be obsolete tomorrow.

Research today is a basic fact of life, and industry is constantly being asked to provide greater speeds, which in turn require radical new design concepts, new materials, new fuels of higher specific impulse, new remote control systems of microsecond reaction time, and new complete reliability. Convair is meeting these specifications today and, with the capability of their research and development laboratories, will be able to anticipate tomorrow's state of the art and technological breakthroughs.

Substantial sums have been invested in scientific studies at General Dynamics/Convair, and few companies can match, in depth or versatility, Convair's technical competence. It is logical to assume that a greater investment will be made in research during the coming years.

Convair's achievements, over a wide product range, originated in company-funded facilities and laboratories. Among these are Electrical and Electronics Facilities; Flight Test Facility; Materials and Processes Laboratory; Calibration Services, or Standards, Laboratory; Structures Laboratory; Thermodynamics Laboratories; and Wind Tunnels.

All of these, and more, research facilities are available for use by all operating divisions of the General Dynamics Corporation, and for use by other industries wishing to utilize Convair's extensive laboratories and the capabilities of trained teams of technical personnel.

The General Dynamics/Convair research and development laboratories reviewed in this issue are the result of a continuing planned facilities program. Further information on these facilities with reference to their use for specialized research and testing requirements may be obtained by contacting Mr. H. E. Wolfe, MZ 11-00, GD/Convair, San Diego, Calif. 92112.

## Electrical Facilities

The electrical laboratory, a function of the electrical design group, is operated in support of design, field service, and ground support engineers. Facilities and personnel permit tests and evaluation over a wide range of subjects from instrumentation to power generation and distribution. Following are a few of the functions performed in the Electrical Laboratory.

■ Evaluation of basic electrical and electronic components such as terminals, wiring, relays, switches, circuit protectors, resistors, lights, etc.

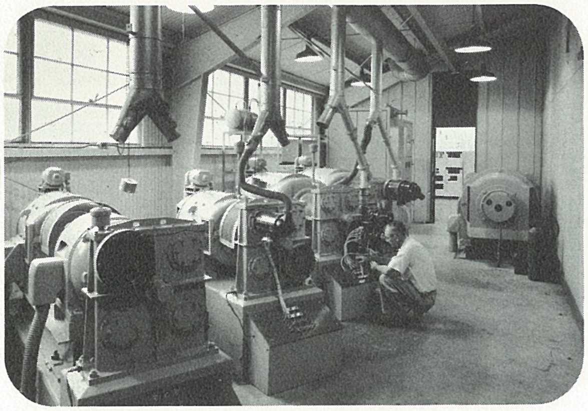
■ Evaluation of systems operation characteristics and reliability.

■ Life-cycling of components and systems over a wide range of ambient conditions of temperature, frequency, and voltage.

■ Evaluation of alternating and direct-current generating and distribution systems, including constant-speed devices.

■ Generation and control of typical switching transients.

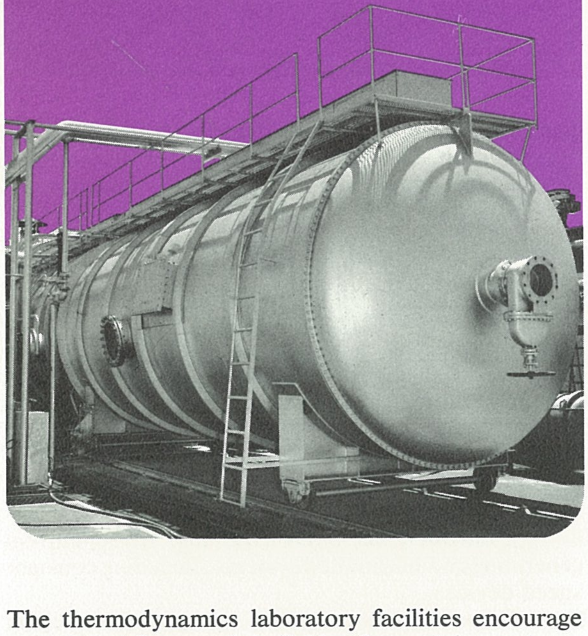
■ Investigation of field service problems and evaluation of remedial measures.



This facility, in cooperation with the Equipment Design Group, is qualified to do expanded research and development on the following systems and components:

- A-C and D-C aircraft power generation and distribution.
- High- and low-power switching, and voltage surge control switching.
- Internal and external aircraft lighting.
- Aircraft fire and smoke detection.
- Circuit protection devices.
- Electrical instrumentation.
- Reliability studies and tests.
- Emergency power systems.

## Thermodynamics Laboratories



The thermodynamics laboratory facilities encourage experimental research in fields of propulsion and propulsion fluids, gas dynamics, rocketry, environmental control, and cryogenics. The organization keynotes flexibility, permitting experimental support of major programs as well as independent research.

### *PROPULSION DEVELOPMENT*

Propulsion development facilities are geared to operate two turbofan and afterburning turbojet engines (up to 30,000 lb thrust at 500 lb/sec airflow) for performance evaluation and qualification and functional testing.

### *JET EXPANSION AND RADIATION STUDIES*

A rocket-powered wind tunnel has been developed and used for high-velocity high-temperature research. Another area of interest has been the evaluation of flame deflector configurations using a $^1/_{30}$-scale Atlas model. Erosion resistance of many materials has been determined by subjecting them to high heat flux and dynamic pressure of rocket exhaust impingement. Rocket engines, ranging from 1 to 800 pounds thrust, and their associated propellant and ignition systems, have been designed and installed for these tests. In addition to sea level operational capabilities, vacuum facilities are available for rocket operation at pressure altitudes up to 130,000 feet. Two 1000-cubic foot tanks, 6 ft. in diameter, are in use as altitude chambers. The rocket test facility is used extensively for static rocket experimental work, base heating, flame expansion, and plume radiation programs. Material evaluation studies under simulated high Mach number flow conditions are also conducted.

### *CRYOGENIC STUDIES*

A study has been completed in which cryogenically cooled surfaces were used to maintain a vacuum while admitting gaseous $N_2$ and gaseous $H_2$ into the vacuum chamber. Liquid $H_2$ and liquid He were used in the condensing circuits. Flow rates as high as 0.008 pounds per second of gaseous $N_2$ were successfully condensed while maintaining the vacuum in the range of 20 microns of Hg. As a part of this study, techniques for temperature measurements from 4° to 80° K were developed.

### *CONTROLLED TEMPERATURE CHAMBER*

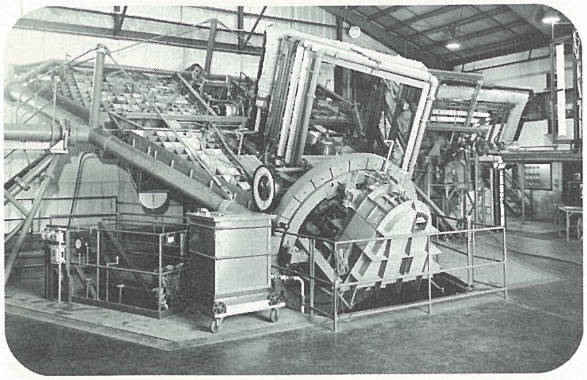
A 15 × 15 × 27-foot environmental chamber is available for full scale air conditioning studies, or investigations of mechanical component operation at temperatures from −100° to +300°F. The chamber has a cooling capacity of 100,000 Btu/Hr at −100°F. A 60-kw bank of heaters will raise the temperature of the empty chamber to 300°F in two and one half hours.

### *AIR FLOW CAPABILITY*

The Thermodynamics Laboratory has facilities for the development, qualification, proof-testing, or certification of ducts, valves, actuators, instrumentation, pneumatic systems, air conditioning systems, air turbine motors, gas turbine compressors, and a multitude of other items requiring a facility capability mix of high flow rates, high temperatures, high pressures, environmental control, and data gathering.

Steam ejectors and ignitron electric power controls provide altitude environment capability and radiant thermal environment simulation.

### *FUEL AND OIL SYSTEMS TESTS*



Fuel system evaluation tests are designed to demonstrate reliability and performance of a system under many simulated flight conditions. Fuel systems can be operated to duplicate all basic airplane system parameters of flow, pressurization, altitude, attitude, temperature, rates of climb, dive, pitch, and roll.

For attitude control, the test specimen is gimbal-mounted in two axes, and all required fluid and electrical conduits are swivel-mounted or otherwise flexibly connected. Full operation of a specimen can be accomplished as it is positioned through combinations of pitch to ±90° and roll to ±60°. Rates of attitude change are controlled by means of a variable speed electric drive.

Electronic programming controllers provide fuel-flow rate changes simulating typical flight envelopes.

A separate laboratory is operated for development and evaluation tests of fuel system components. Such items as fuel pressure regulators, shutoff valves, flow control valves, and fuel booster pumps are tested on a flow bench capable of simulating actual operating conditions.

Tests can be made with heated, very cold, and water-contaminated fuels.

### *WINDSHIELD CLEARING*

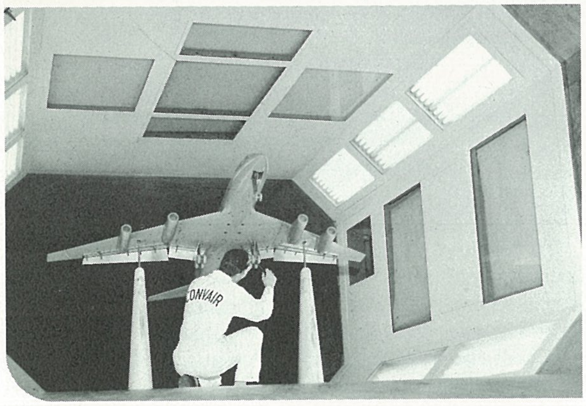
A tunnel configuration that was recently used for F-111 studies, produced free jet velocities at the windshield in excess of 200 mph. High-pressure air from the high-speed wind tunnel is used as the primary power for ejector tunnels.

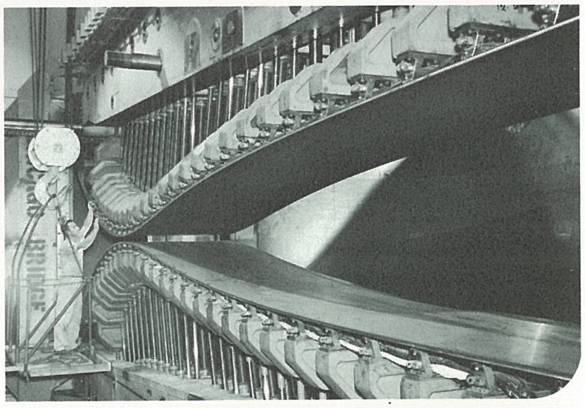
A pressurized water supply tank forces water through spray bars in the tunnel section to produce simulated rain.

Metered air at controlled temperature and pressure is supplied to the rain clearing nozzles. Structural and windshield temperatures are recorded.

A wash solution is injected into the clearing air stream in a timed cycle for salt-spray and insect deposit clearing studies.

## Wind Tunnels



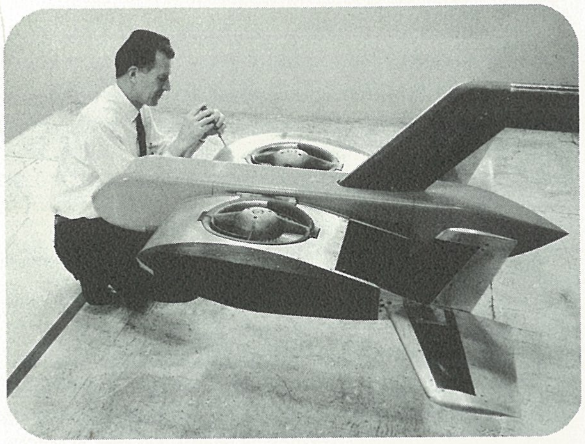


Convair operates two wind tunnels for the parent General Dynamics Corporation. These facilities are invaluable in both the design and development of new aircraft and missiles and for research into basic aerodynamic processes.

Wind tunnels simulate flight by moving air over a small model rather than moving the model through the air. They are generally rated by the airspeed they can produce. Convair's two tunnels cover low-speed flight (0 to 350 mph) and high-speed flight (350 to 3800 mph).

The Convair low-speed wind tunnel has a working section 12 feet wide and 8 feet high, permitting the testing of models with wing spans up to 11 feet. Convair 880/990 models, to 0.04 scale, were tested extensively in this tunnel during the development of these aircraft.

Models of flight vehicles are subjected to forces and pressures exerted on the models by the airflow. These forces and pressures are measured by mechanical and electronic equipment, and the information is directly related to conditions encountered in actual flight.

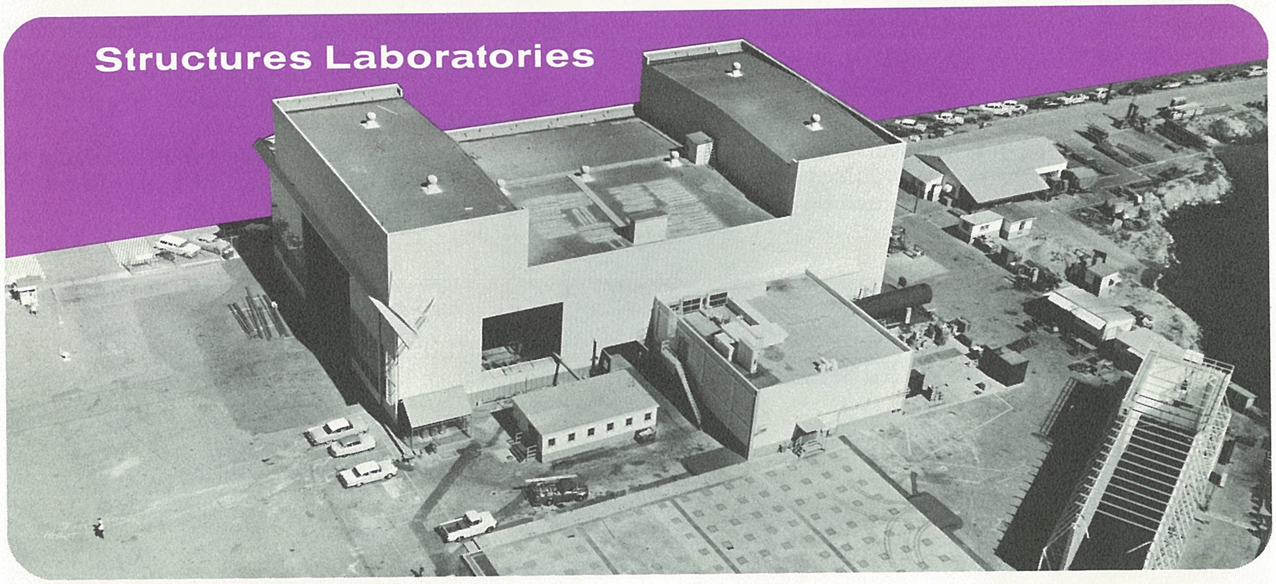


The low-speed tunnel is equipped with a number of features which make it one of the most modern of its kind in the country. In addition to advanced measuring equipment, it has a large VTOL test section and model motor power equipment. The large test section (20 × 20 feet) provides a facility for studying the very low-speed flight associated with STOL-VTOL aircraft. The model power facilities allow the use of variable speed model motors to drive model scale propellers and fans.

The Convair high-speed tunnel has a working section of 4 × 4 feet. Models with a span up to 2.5 feet can be tested at Mach numbers from 0.5 to 5.0. The tunnel is an intermittent type with run times of 45 seconds to two minutes. The high-speed tunnel has been used to develop the F-111 tactical fighter, the Atlas, Redeye, Terrier, Mauler, and Tartar missiles, and many other configurations.

The high-speed tunnel is equipped with an electronic data system and an on-site digital computer. It is powered by an 8000-HP compressor system.

## Structures Laboratories



The Structures Laboratories are equipped to perform static, fatigue, impact, and pressure tests, and to record this information. In this facility, the complete F-111 will be subjected to fatigue, static, and drop tests to destruction.

It was in these facilities that the Convair 880 was subjected to a year-long program of proof-load testing.

A complete description of the test facilities available is too long to publish here, yet some of the following objectives in testing of the 880 indicate the range of testing that can be focused on a complete airplane.

Hailstones, the size of golf balls have been fired against samples of the wing and tail leading edges to determine if such oversized hailstones would impair structural integrity of the airplane.

To test the strength of the windshields, birds were fired at near sonic speed into the windshield. Tests involved use of a 450-knot compressed air gun, capable of firing the bird at velocities far above the cruise speed of the airplane at altitudes at which birds might be encountered.

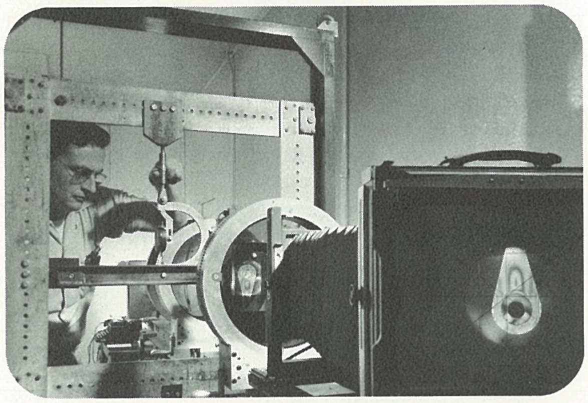
In other tests, wing stringers and fuselage skin were cut and a load applied to produce failure of the section at or above the fail-safe load of 53.5 percent of design limit load. If no appreciable growth of the crack developed, the cut was increased and the procedure repeated until the member failed.

Numerous segments of the fuselage were subjected to cyclic cabin pressure fatigue tests with pressures up to 9.3 psi. A 19-inch javelin blade was forced through the skin and beltframes while the specimen was pressurized, so as to determine crack growth.

## *SOUND SUPPRESSION*

Research in sound suppression is centered in the acoustics facility. Electronic noise generators, amplifiers, and loud speakers, project the complete audible spectrum from 15 to 15,000 cycles per second, or any desired single frequency or band of frequencies, into a reverberation chamber. A sample of skin damping materials under test reflects, transmits, or absorbs this sound in varying degrees. The amount of noise that escapes through the sample into the anechoic chamber is measured.

## *STRESS ANALYSIS TECHNIQUES*



The latest experimental stress analysis techniques utilize a photoelastic method. The polariscope used in this method has an 8-inch viewing field and a Babinet Soliel compensator for precise measurement of fringe values; an 8 × 10-inch plate camera is used for making permanent records.

Another method of stress analysis uses Photostress, a thin plastic photoelastic material which is cemented to the structure to be analyzed, allowing great versatility.

## *TENSION COMPRESSION TESTING*

A 400,000-pound capacity universal testing machine operates in tension or compression, handling specimens up to 11 feet long. A million-pound capacity hydraulic cylinder is capable of accommodating large 5 × 14-foot specimens.

Static loads, repeated loads, and spectrum fatigue tests are programmed by a hydraulic load programmer. Five continuous strip chart function generators provide basic program command. One of the five function generators controls a switching system and programmer to modify load levels produced by the other four function generators.

## *ELEVATED TEMPERATURE TEST FACILITIES*

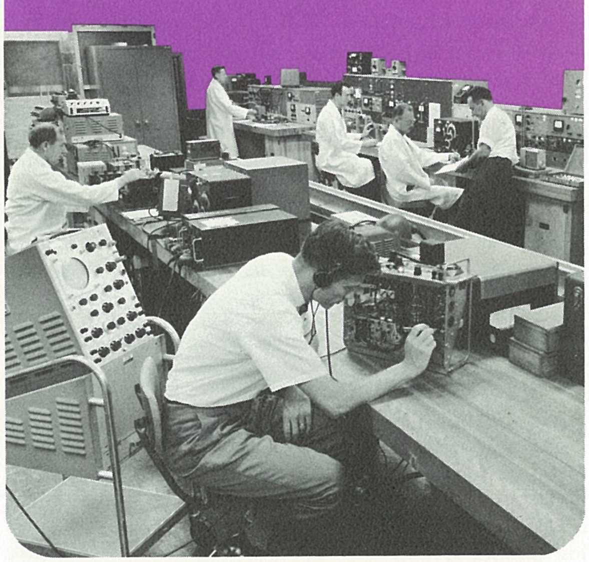
The elevated Temperature Test Facilities consist of an analog computer-programmer, an a-c power supply, power controllers, a power distribution network, and infrared lamp heating elements.

Test modes possible with the computer-programmer include temperature versus time, heat flow versus time, and the aerodynamic forced convection heat flow equation. All are closed-loop test modes with thermocouple or electrical power feedback.

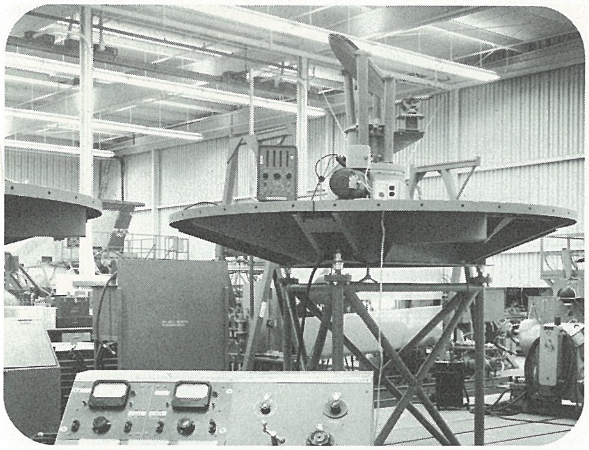
The independent power system uses two transformers capable of a continuous 3000-kva output, or 6000-kva for five-minute test periods.

Radiant heat is furnished by quartz infrared lamps $^3/_8$ inch in diameter and 9 to 29 inches long. The heat sources, in addition to aerodynamic heating simulation, are readily adaptable to simulation of rocket, turbojet, solar or nuclear reactor heating, and to simulation of thermal radiation of a nuclear detonation.

# Electronics Facility



The Electronics Facility is comprised of several integrated sub-laboratories, or groups. All test equipment is pooled, enabling tests to be conducted with equipment drawn from another facility, or the testing being done by one of the sub-laboratories. Following are some of the laboratories in this facility.



*The Antenna Lab* has all the facilities necessary to conduct research, design, and development of antenna systems over a frequency range of 100 kc to 70 kmc.

*An Infrared Optics Technology Laboratory* conducts work in the wavelength region extending from ultraviolet to infrared. Facilities are specifically oriented toward component fabrication and test and research, or measuring.

*The Radar Signature Laboratory* conducts theoretical and experimental analyses of radar cross-section or radar signature. Included in the facility is equipment that can accurately locate and measure flare spots, study basic behavior of scattering cross-section for either simple or complex targets, and identify most radar targets.

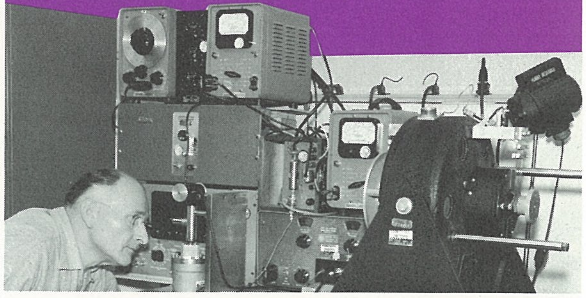
Included also in this laboratory are facilities for conducting microwave and optical analyses of the behaviors of hypervelocity projectiles and their ionized wakes; a section of tunnel in the hyperballistic range at Ames Research Center has been equipped and fully instrumented by Convair to measure Doppler return, back-scattered return and signal attenuation by the projectile in its wake.

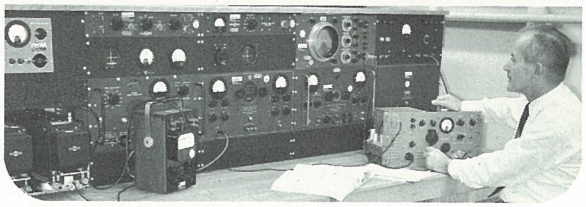
*The Electronic Interference Laboratory* has a complete HF, VHF, UHF mobile communication and data-recording trailer for in-flight antenna radiation pattern tests and other special communication tests.

*The Radomes Test Laboratory,* which has been actively engaged in the design, development, and testing of radomes for the past decade, has range facilities which automatically measure and record boresight shifts and transmission efficiencies of radomes up to five feet in diameter and fifteen feet in length. Also included in the radomes group are: a high-temperature cavity perturbation dielectrometer capable of measuring dielectric constant and loss tangent of materials at X-band frequencies; a microwave interferometer for measuring the insertion-phase-delay and transmission of microwave energy; a completely automatic microwave antenna for recording the phase and amplitude distribution of antenna near fields.

*Guidance and Control Facilities* are equipped to design, develop, and evaluate all types of servo mechanisms and associated electronic circuitry.

## Standards Laboratories





The great technological advancement in the fields of supersonic aircraft and long-range missiles during the past decade has been largely dependent on parallel growth in the accuracy of measurement techniques.

In the Standards Laboratories, a competent technical staff of engineers and a vast assemblage of precision measurement equipment is available for both large- and small-scale instrument calibration and repair tasks. The development of highly refined and efficient techniques, and the duplication of test equipment and reference standards permit utmost speed, accuracy, and economy in the performance of all tasks assigned to the laboratories.

Convair's Standards facility, with its capable engineering staff, has assisted medical groups, schools, test laboratories, engineering concerns, and military groups in the repair, calibration, and certification of industrial and scientific instruments. Calibration is accomplished through comparison with standards validated regularly by scheduled recertification at the National Bureau of Standards. The following calibration and repair facilities are available.

Microwave measurements and repair of AR, FR through VHF, and in all waveguide bands to 40 kmc. Standards are maintained for frequency power, phase, standing-wave ratios, field strength, and attenuation.

Accurate measurement of electrical quantities such as a-c and d-c voltage to 60,000 volts, a-c and d-c power to 100 amperes, power resistance from 0.000001 to $10^4$ ohms, capacitance and inductances. The frequency range of a-c measurements is up to 10 kc.

In the mechanical calibration facility, the standards lab has a wide range of capability for measurement of pressure, flow, viscosity, vacuum, force, vibration, and acceleration.

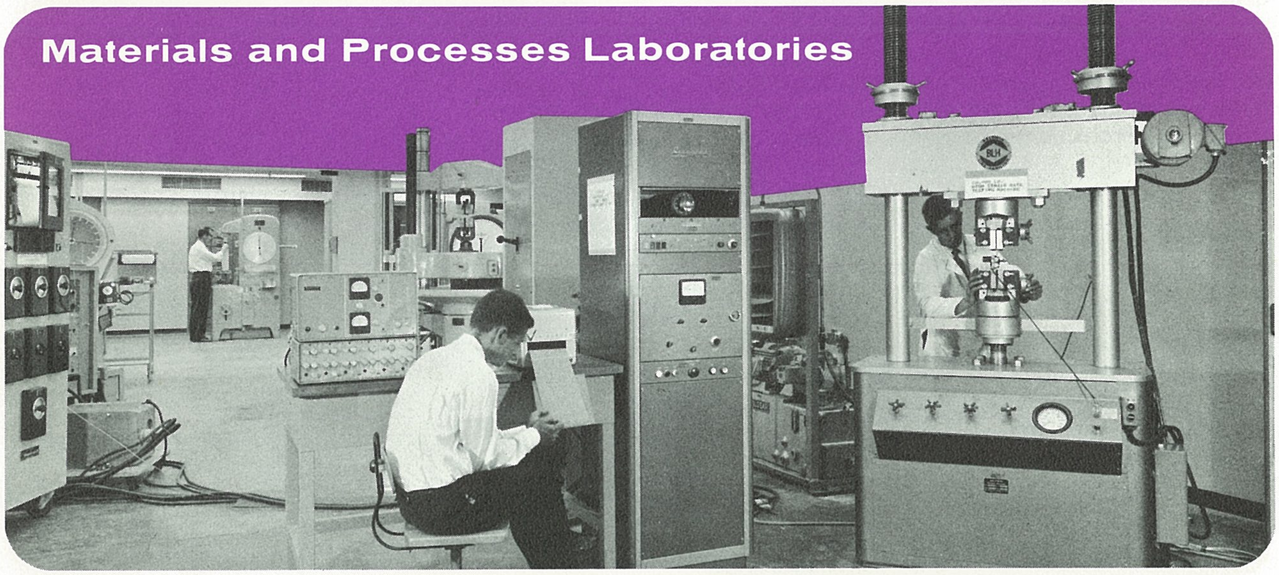
In the physical calibration facility, apparatus is maintained for fundamental measurements of such elements as mass, length, temperature, light, etc; and for calibration of nuclear survey equipment.

## Flight Test

The Engineering Flight Test Facility provides the management, technical skills and facilities for planning, directing, conducting, analyzing, and reporting results of all flight test programs and missions for aircraft and missiles. Complete operations support is maintained in handling and solving operational and technical problems with off-site bases. The data station is continually updated to increase its capabilities and economical operation. Following are some of the facilities and capabilities of the data station.

- Simultaneous receiving, recording, and monitoring of telemetered signals from in-flight test programs; two-way communication with the test vehicle, providing safe and efficient tests with ground surveillance of all critical items.
- Processing of analog data from airborne magnetic tape recorders. Time histories which can be presented on 32 channels of Sanborn rectilinear direct-writing records or on five 12-inch CEC recording oscillographs.
- Production of magnetic tapes for storage of final data.
- Two-axis function versus function plots of digital or analog data.
- Spectrum analysis of dynamic data by means of Technical Products Analyzer and presented on X-Y plotter.

## Materials and Processes Laboratories



Staffed by a highly competent team of chemists, metallurgists, and engineers, the Materials and Processes Laboratory is meeting the challenge of an increasingly complex technology. This laboratory is continually being expanded and modernized to cope with the development of supersonic aircraft, missiles, and spacecraft. Lending support to this facility are shop personnel with such equipment as jigs, lathes, mills, grinders; and an excellent library staffed by professionally trained librarians to maintain voluminous books, journals, and reports.

*Mechanical Properties Facility* is equipped to obtain tensile, compression, flexure, shear, and bearing strength data for temperatures ranging from liquid nitrogen to the melting point of the specimen. A considerable amount of mechanical property data have been accumulated on titanium alloys in a test series which is part of the Department of Defense titanium sheet-rolling program.

*Creep Facility* is equipped for investigation of conventional creep when temperature and stress are kept constant over a period of time; and cyclic creep of materials when stress is a variable and temperature is constant; also when temperature is variable and stress is constant.

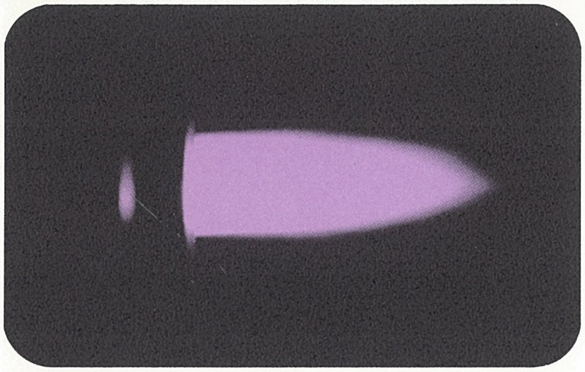
*Heat-Treat Facility* has the equipment and capabilities required for the highest strength-weight ratios consistent with notch sensitivity. Equipment is available for annealing, normalizing, hardening, tempering, or drawing, solution heat-treating, aging, martempering, austempering, iso-thermal transformation, brazing, stress relieving, sintering, metallizing of ceramics, and Hominy hardenability testing.

*Vacuum Metallurgy Laboratory* allows economical bright brazing of high-temperature alloys and stainless steels, without the costly enveloping techniques required by conventional furnaces. Other vacuum-furnace processes include degassing of refractory metals, and ceramic metallizing by the active alloy method.

*Welding Capabilities* provide an effective means for development of minimum-weight structural joints and attachments required by high-performance aircraft and space vehicles. The Welding Laboratory provides the following services: conventional fusion, resistance welding, tungsten-inert-gas, manual-inert-gas, and arc welding.

*The Ceramics Laboratory* has developed flame-spray and plasma-jet spray techniques for the manufacture of high-temperature ceramic components and for the application of thermal protection coatings to metal structures. Included in the testing are ceramic adhesives for metal-to-metal bonding and slip coatings for the protection of titanium and molybdenum during heat treatment. Also important in the evaluation of ceramic bodies are continuous weight loss, deformation under load, melting point, wettability, and controlled atmosphere cyclic effects.

*The Thermal Properties Laboratory* has become increasingly important in the design and construction of high-performance aircraft and space vehicles where temperature protection and control must be maintained.

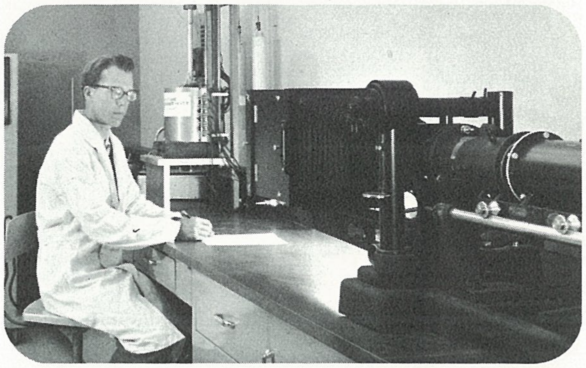


The laboratory's plasma-jet facility has proved valuable for simulating aerodynamic heating of re-entry vehicles and missile nose cones. Mass flow of the atmosphere around the body is obtained; and the physical constants of components used in thermal protection are evaluated.

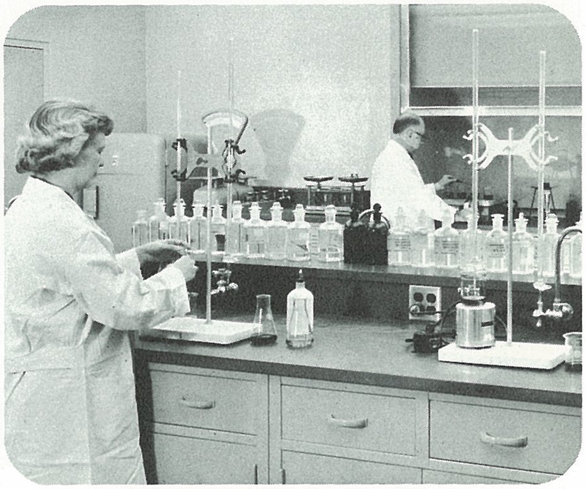
*The Metallography Laboratory* prepares samples for macroscopic and microscopic examination, and documents its findings photographically.

*With X-Ray Diffraction* equipment, stress and fatigue analyses are possible. The symmetrical array of atoms in a crystalline solid produce a diffraction effect when irradiated by x-rays, allowing determination of type and degree of crystallinity and phase change in metals subjected to temperature variation.

*Emission Spectroscopy* is capable of taking minute quantities of an element for rapid analyses, both qualitative and quantitative. With this process, non-destructive analysis of finished parts is conducted and corrosion products readily examined for metallic elements.



*The Analytical Laboratory* is thoroughly equipped for the performance of every type of inorganic quantitative chemical analysis. Methods of analytical chemistry provide the means for complete identification of unknown substances, and only through chemical analysis can the conformance of materials to established composition specifications be determined.



12 54

*Microchemistry and Bacteriology* methods permit analyses when only minute amounts of a substance are available. Microanalysis includes crystallographic characterization and identification of compounds, estimation of purity, analysis of mixtures, and determination of refraction indices of solids and liquids. Microbial growth and material contamination effects and measures for their control are studied in the Bacteriology Laboratory.

*Radiochemistry* involving radioisotopes, for example, have saved industry thousands of dollars, and have become an important tool of the scientist in fields of research and development. In isotope tracer studies, radioisotopes have been used to examine reaction rates, absorption, corrosion, mechanisms of bonding, diffusion, wear, lubrication, and for many other phenomena. Radioisotopes are also used in activation analysis, isotope dilution analysis, and autoradiography.

*Vacuum Fusion gas analyzer* studies the minute quantities of gaseous impurities trapped in metals, either as occulusions, in solution, or in chemical combinations, to determine the effect on the properties of the metals. This equipment is also used to determine the oxygen and hydrogen content of titanium alloys.

*Nuclear Magnetic Resonance and Mass Spectrometry* facilities are available for obtaining information on the composition of materials, analysis of fast reactions such as flames and explosions, and for determining the composition of gas mixtures; for studying and analyzing compounds and solutions which contain hydrogen or fluorene.

*Plastics and Adhesives Laboratory* studies fiber-reinforced plastic materials such as phenolics, melamines, epoxies, silicones, and polyesters, and examines the basic phenomena associated with adhesion and adhesives. These studies are important in the development of nose cones, control surfaces, heat and sound insulators, and plastic structures.

*Finishes Laboratory* is engaged in the research and development of protective and decorative finishes to meet the specific problems encountered in modern jet and missile flight.

*Corrosion Laboratory* is equipped to utilize the natural environmental conditions of the San Diego bay area for conducting seashore exposure and seawater immersion testing. In housed facilities, the laboratory conducts studies on electrochemical corrosion phenomena, inhibition, cathodic protection, high-temperature oxidation, and accelerated environmental testing.

*Electrochemistry Facilities* develop new metal finishing techniques and improve the old ones through use of electrochemical and catalytic processing. Facilities are available for performing all types of test and development work ranging from metal cleaning prior to finishing, to electroless platings for wave-guides and printed circuits. Performed also are tests on metal cleaning, descaling, ultrasonics, deionization, chemical milling, conversion coatings, and anodyzing.

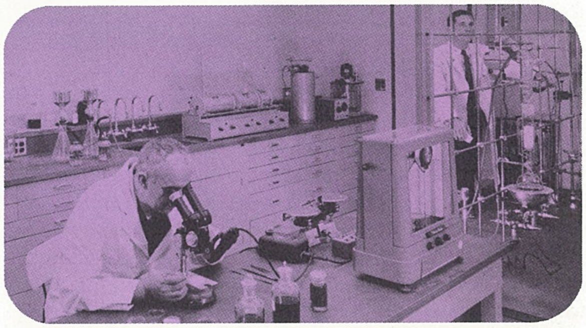
*Ultra-High Vacuum Laboratory Facilities* attain pressures in the order of $10^{-9}$ mm Hg. High vacuum systems are used to simulate conditions of outer space in order to study friction, lubrication, bombardment of charged particles, ablation, optical, and mechanical properties.

*Hazardous Tests* are conducted in an area set aside from the main laboratories for such experiments as safety of materials with gaseous or liquid oxygen, flame-resistance of materials, chemical reactions which may be violent or explosive, heated bomb vapor-pressure measurements, and tests with heated fuels.

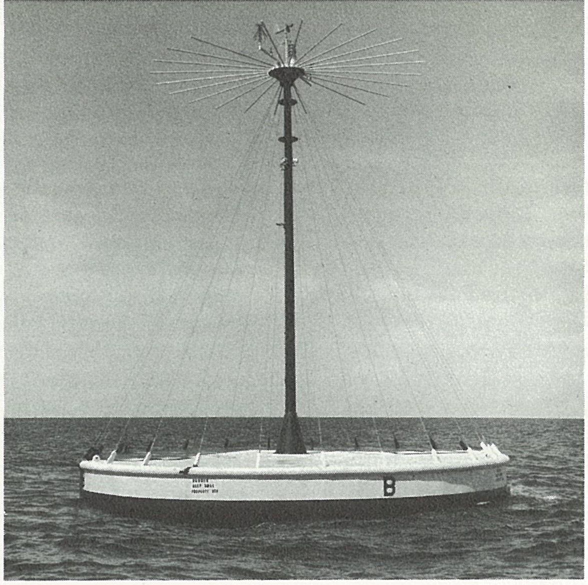
*Glass Blowing* supports the activities of the Materials and Processes Laboratory in the fabrication and repair of glass apparatus. Special Dewar flasks and complete vacuum systems are among the research and standard equipment which have been fabricated for the wide variety of experiments conducted by the laboratory. Included are heat-resistant glass, quartz, soft glass, standard joints, stopcocks, and glass-to-metal seals, two lathes, annealing ovens, and the usual glass-working torches.

*Organic Chemistry* facilities provide for tests of physical and chemical properties of aircraft fluids; solid and liquid rocket fuels; plastics of all types; films, foams, and paints. Quantitative determinations of elements such as nitrogen, sulfur, chlorine, carbon, and hydrogen project a clear picture of unknown materials when combined with other physical and chemical tests conducted in the laboratory. Data sought in these tests include boiling or distillation range, melting point, refractive index, color, magnetic properties, density, surface tension, heat capacity, and viscosity.

12 54



*Chemical Processes Laboratory* provides a central location for ball mills, mixers, centrifuges, ovens, and other chemical processing equipment for general use. Paint compounding, ceramic frit grinding, sealant preparation, heterogeneous material separation, and similar activities are conducted in this laboratory. Qualification tests are made on newly developed room-temperature-vulcanizing and sheet rubbers to determine suitability for use as fuel tank, cabin pressure, O-ring and general aerospace seals.



# Convair Develops Telemetering Buoy System

A NEW TELEMETERING BUOY SYSTEM that could send scientists a steady flow of previously unavailable oceanographic data is being developed by General Dynamics/Convair for the office of Naval Research.

Objective of the program is to develop a much-needed system for gathering and storing oceanographic and atmospheric data and transmitting such data to shore stations from thousands of miles at sea with maximum reliability and utility.

Fourteen models of different shapes were tested in the Convair towing basin, largest facility of its kind on the West Coast. These studies showed that a discus-shaped buoy hull would best meet the various requirements. A model of this configuration was then subjected to simulated typhoon winds, waves, and currents in the towing basin. A large wind machine, which moved along the basin ahead of the towing carriage, was built especially for this purpose.

The discus-shaped buoy is 40 feet in diameter and is topped by a 40-foot mast that supports a discone antenna which enables the buoy's electric power system to get air from a point high above the surface.

The buoy is a relatively stable unit that supports the antenna with a minimum of motion. It is designed to weather 60-foot waves, 10-knot currents, and 150-knot winds—all while floating on the surface and anchored in depths exceeding 20,000 feet.

A slack line that is one and one-half times the water depth will probably be used to moor the buoy. Electric sensors attached to the line take various measurements such as water temperature at various depths, current direction and velocity, and light transmission through water.

The buoy has 100 sensors, or channels, which gather, store, and send oceanographic and atmospheric data, such as wind velocities, air temperatures at the surface, barometric pressure, etc. The scientific data is stored in two memories: one is a short-term, 24-hour memory; while the other is a long-term memory capable of storing data for the entire one-year period it will function. It is planned to query the buoy every six hours and collect all the information accumulated during the previous 24 hours.

The first prototype buoy was launched by the Navy in Jacksonville, Florida, in August. Fabrication of a second buoy is scheduled for tests off the coast of California in March.

In the Florida tests, technicians will monitor performance from a mobile command/receiving station, which is actually a converted passenger bus that will be driven from place to place to make tests. The bus contains all the equipment required to command and receive data from the temporary FM/FM telemetry package in the buoy. Following these tests the buoy may be moved to extremely deep water in the Bahama Islands, to permit study of the buoy's behavior in deep water, and also the effectiveness with which the mooring line supports the various instrumentation packages strung along it. In California, the behavior of the energy conversion system equipment will be studied, and there will be an evaluation of the suitability of the buoy as an environment for the electronics equipment it will eventually contain.

Final phase of the testing will be the actual transmission of oceanographic and atmospheric data from the buoy to the mobile shore station (the bus) by shortwave radio over distances up to 3000 miles.

A network of these information gatherers, scattered strategically around the world's water would give oceanographers and meteorologists a synoptic record of air and water phenomena previously unobtainable or incomplete.

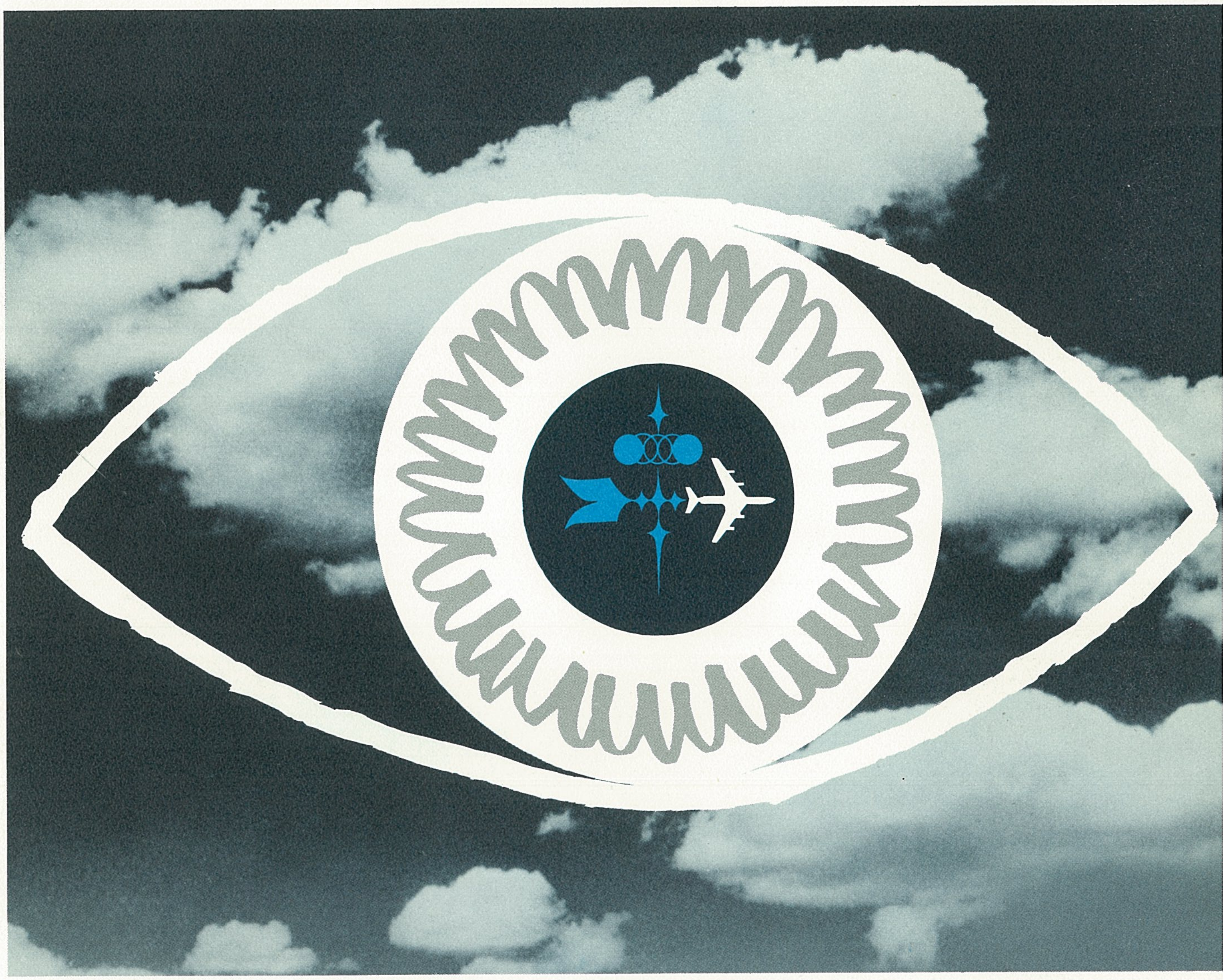
With development of a workable system, GD/Convair, as a leader in this little-explored field, will be equipped to produce both data transmission systems and buoys.

**GENERAL DYNAMICS | CONVAIR**

12 54

VOLUME XVI NUMBER 6 MARCH | APRIL 1965

# Convair Traveler



In This Issue: An Eye on the Weather

VOLUME XVI NUMBER 6 MARCH|APRIL 1965

Convair Traveler

*In This Issue: An Eye on the Weather*

OUR COVER

The weather you are enjoying—or enduring—today may be the result of air that drifted in from the Pacific or Atlantic oceans, from the Gulf of Mexico, or from the chill Arctic. The point of origin of this air and its course is charted by thousands of eyes around the world to give pilots—and anyone else who is interested—a synoptic picture of the weather. Artist for this issue is George Paul.

# *Convair Traveler*

**VOLUME XVI NUMBER 6 MARCH/APRIL 1965**

MANAGER, CUSTOMER SERVICE—**O. W. HARPER**
CHIEF ENGINEERING SERVICE—**L. J. BORDELON**
CHIEF, FIELD SERVICE—**R. E. SOMMERS**
MANAGER, SERVICE PARTS—**J. DOIG**
MANAGER, TECHNICAL PUBLICATIONS—
**H. R. KENNEDY**
EDITOR—**GERTRUDE S. HUNTER**

**IN THIS ISSUE**

**PAGE 3**

AN EYE ON THE WEATHER

**BACK COVER**

T-STORM SEASON

A digest of operation and service published monthly by the Technical Publications Section of GD|Convair, primarily for the interest of Convair operators. Permission to reprint any information from this periodical must be obtained from the Chief of Technical Publications, General Dynamics|Convair, San Diego 12, Calif. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without the specific approval of their cognizant organization.

**COPYRIGHT 1965**

**GENERAL DYNAMICS | CONVAIR**

He that pryeth into every cloud may be struck by a thunderbolt ... J. RAY

# An eye on the weather

FORTY YEARS AGO, about the time air carriers were accepting their first paying passengers, airplane departures depended on the weather . . . aircraft were not dispatched if it was raining, or even if it looked like it might rain.

When air carriers first began depending on standard weather forecasting, they found that these forecasts were usually only about 65% correct—about the same odds given on such old wives' tales and homespun predictions as aching corns, electricity in the hair, chirping crickets, and the like.

As weather forecasting became more reliable, takeoff schedules became more reliable, and airlines were gaining the confidence of the airminded public.

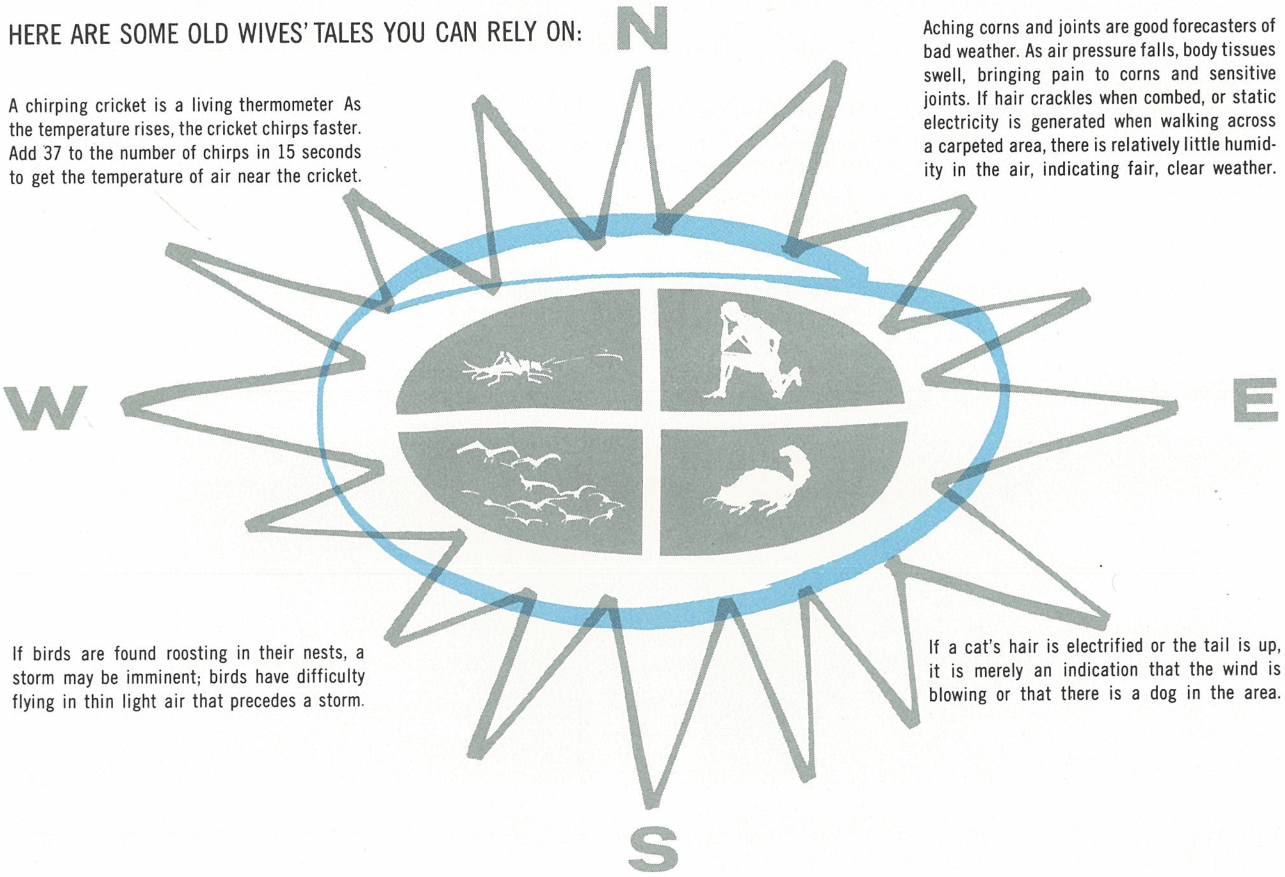
In those early flights, passenger comfort was not a major consideration. A smooth ride was more often the exception than the rule. Flights were, of necessity, made at low altitudes, and the instruments necessary to guide pilots through storm areas and low ceilings to a smooth landing were, as yet, undeveloped.

Today, the pilot gets a weather briefing for his complete flight plan—whether it is a short-range, cross-country, or intercontinental flight. These weather briefings are a composite of information received from many sources and for many purposes.

*Short-range forecasts,* prepared and distributed by the various weather bureau offices throughout the United States, accurately predict weather conditions for one or two days. The forecasts include such information as ceilings and visibilities, temperature, wind direction and velocity, areas of severe weather, cloud cover, and other pertinent information. This information is supplemented as often as necessary to keep up with the changes in the weather.

*All photos in this issue (except figure 18) are courtesy of United States Weather Bureau.*

HERE ARE SOME OLD WIVES' TALES YOU CAN RELY ON:



A chirping cricket is a living thermometer As the temperature rises, the cricket chirps faster. Add 37 to the number of chirps in 15 seconds to get the temperature of air near the cricket.

Aching corns and joints are good forecasters of bad weather. As air pressure falls, body tissues swell, bringing pain to corns and sensitive joints. If hair crackles when combed, or static electricity is generated when walking across a carpeted area, there is relatively little humidity in the air, indicating fair, clear weather.

If birds are found roosting in their nests, a storm may be imminent; birds have difficulty flying in thin light air that precedes a storm.

If a cat's hair is electrified or the tail is up, it is merely an indication that the wind is blowing or that there is a dog in the area.

*Local weather,* as observed by a local office of the U.S. Weather Bureau (San Diego, for example), may predict a "low overcast, coastal regions." This overcast may indicate rain to a mid-westerner, but to the San Diego Weather Bureau, this cloud cover indicates a situation that is a result of the Pacific sub-tropical high-pressure center that is prominent in this area in the late spring and summer.

*The long-range forecast* gives a generalized weather picture to cover a period up to 30 days. This forecast does not predict the day it will rain, but does indicate the above- or below-normal precipitation for the entire period.

*How can the weather bureau accurately predict weather over a large region?*

Weather today is generally the result of weather that was in effect in other parts of the world over a week ago; however, new weather situations die and are born every day. Air pressure, temperature, humidity, wind speed and direction, cloud formations, and precipitation are observed by weather observers at weather stations throughout the world. To assist weather stations, pilots report en route weather and the weather they see up to 100 miles away on the radar scope. Reports are also received from ships at sea, which give weather conditions over various parts of the ocean. These reports, combined with the reports received from other parts of the world, and analyzed by meteorologists and weather forecasters, help the weather bureau to make reasonably long-range predictions of weather in various parts of the world. This information is transmitted to weather stations throughout the world in the form of maps, such as the typical one illustrated in figure 1, and in coded observations and forecasts.

Today, instrument-carrying satellites, such as the TIROS, are designed to gather, record, and transmit television pictures of cloud patterns and other atmospheric conditions. Analyses of these synoptic scale situations, which produce our weather on earth, assist the forecaster in preparing reasonably accurate weather information. Presently, these satellites are not oriented to earth; in other words, they have a fixed attitude in space, and photographs are usually taken obliquely instead of straight down.

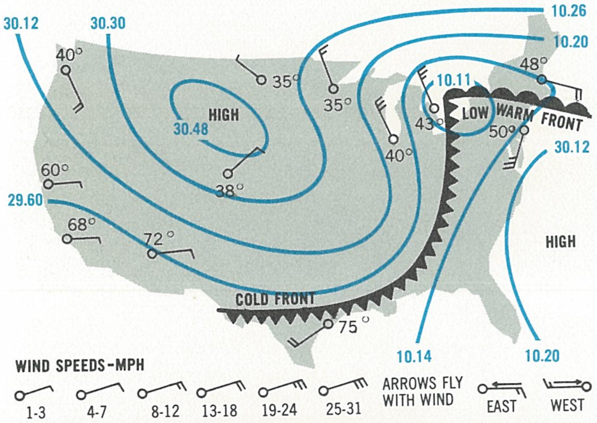


*Figure 1. Simplified weather map showing cold and warm fronts, and isobars (blue lines) connecting points of identical S.L. pressure readings.*

In the near future, a new TIROS will have cameras mounted on the rim of its structure; this TIROS will roll through space, taking pictures only when its cameras are oriented along the local vertical. These satellites, plus ground, air, and marine observations, will provide a global weather picture.

It is an established fact that weather varies with changing temperatures, atmospheric pressure, air motion, moisture content, and other measurable conditions. In fact, these phenomena are weather and all are closely related. Today, the jet transport can encounter all of the four seasons in a matter of hours as it flies over land and sea—from the equator to the arctic—and it can encounter some of the world's hottest and coldest regions in a few minutes as it flies from sea level through cloud layers in the troposphere into the lower stratosphere (see figure 2).

In the troposphere, air circulates vertically and horizontally. It is in this region that clouds and storms occur. The higher one flies in the troposphere, the lower the temperature and the greater the wind speeds.

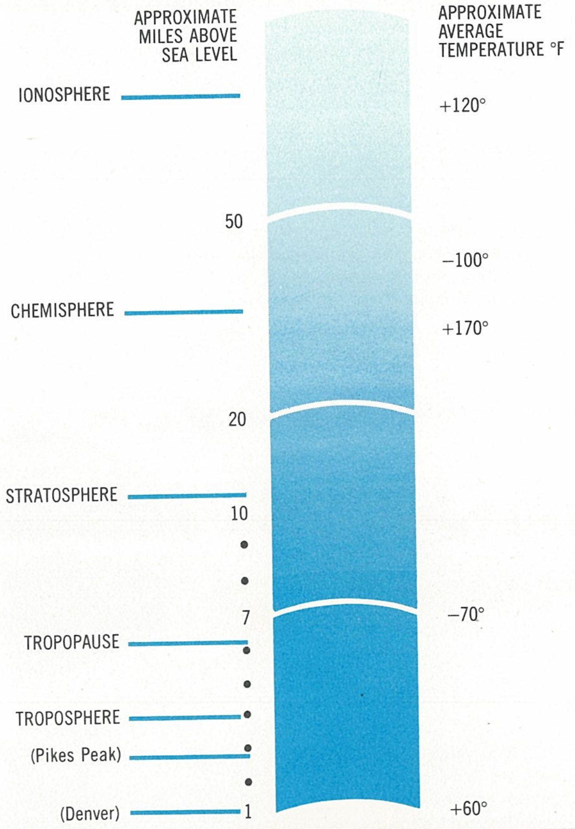


*Figure 2. The atmosphere is built up in layers. A space capsule can encounter the hottest and coldest regions surrounding this planet when flying from sea level high into the atmosphere.*

Jet aircraft usually fly near the tropopause. The tropopause is an imaginary boundary that separates the troposphere from the stratosphere. This boundary is usually quite sharply defined but varies in height by day and season. In the middle latitudes, the tropopause may be at the 25,000- to 35,000-foot level; in the tropics, it is at the 50,000-foot level, occasionally extending to 60,000 or 70,000 feet in the summer. At the poles, the tropopause is around the 25,000-foot level.

Occasionally, when a break is found in the tropopause, moisture will penetrate the lower stratosphere, forming cirrus clouds; otherwise, the stratosphere is dry and cloudless, with air generally circulating horizontally. The stratosphere is nearly isothermal, being characterized by being in a state of radiation equilibrium.

Winds are generally greatest near the top of the tropopause. It is in this area where well-defined streams of air—jet streams—are found, and the pilot can "hitch a ride" that can give him a 75- to 100-knot tailwind. Analyses of clear-air turbulence indicate that it is often observed near jet streams.

Although there are as many jet streams in the winter as in the summer, the wind speeds are greater in the winter. Another difference is that they move farther south in the winter, and farther north in the summer. If a pilot finds himself bucking a strong headwind, he can change his flight path into regions of diminished headwinds.

While jet aircraft generally fly at altitudes above the weather, many types of hazardous weather conditions can be encountered on the way to and from flight altitudes, and it takes careful flight planning, utilization of weather facilities, and a knowledge of clouds to effect a safe and comfortable flight.

In his weather briefing, the pilot investigates such elements as icing, turbulence, thunderstorm activity, winds, and weather conditions at points of let-down, and the possibility of changing weather along his route. The latest weather information may change within a period of five minutes, so he must have a forecast of published minimums, or better, to list a terminal as his destination, and then only with an alternate that is forecast to remain above minimum.

A knowledge of cloud formations helps the pilot to analyze changing weather conditions, and to select a small deviation from his assigned flight path which may offer less turbulence. Although clouds are an important guide to weather, most rules concerning them can vary just as the clouds vary as they sweep across the sky. But, for the most part, clouds fall into four general categories: high, middle, low, and vertically developed.

Clouds probably affect the airline industry more than most other industries. Landings and takeoffs could be more difficult in low cloud formations; flight in middle clouds could cause turbulence and require instrument flight; high clouds could also affect flight; and the vertically developed clouds may bring severe storms and turbulence.

## High Clouds

High clouds have their lower mean level at approximately 20,000 feet. In this category are the cirrus—above and below 45° (figures 3 and 4); the feathery cirrus unicus (figure 5); the patchy cirrocumulus (figure 6), and the thin veil-like cirrostratus. Despite their delicate feathery appearance, cirrus clouds are

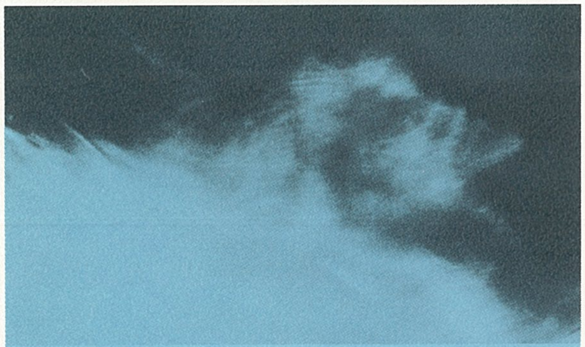


*Figure 3. Cirrus above 45°, often in converging bands, and/or cirrostratus grow denser as they progressively invade the sky. The continuous veil extends more than 45° above the horizon but the covering does not completely cover the sky.*

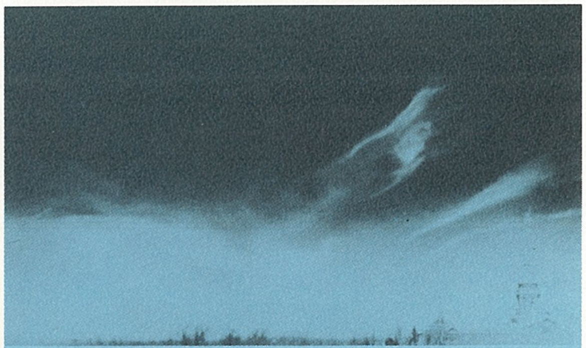


*Figure 4. Cirrus below 45° are often in strands that converge toward one or two points of the horizon. Like the Cirrus above 45°, they grow denser as they invade the sky, but the continuous veil formed does not reach 45° above the horizon.*

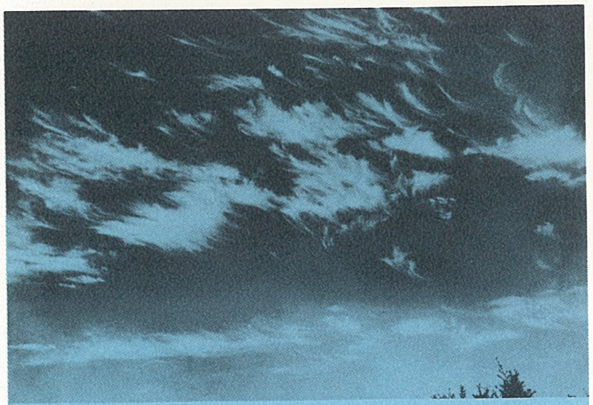


*Figure 5. Cirrus unicus are detached clouds of delicate and fibrous appearance without shading. They are white in color and shaped like a hook, or comma, with upper parts ending in little tufts or points. They progressively invade sky.*

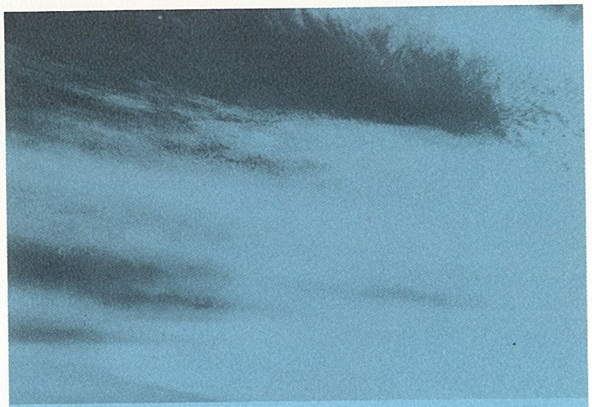


*Figure 6. Cirrocumulus alone or accompanied by cirrus and/or cirrostratus are patches (or a layer) of small flaky or globular masses resembling fish scales. Although white, they often take on red and yellow tinges of sunrise and sunset.*

composed of ice crystals of fairly large size, due to their high altitudes where temperatures are low. Because these clouds are relatively high, they seem to move slowly across the sky, but their average speed is more than a mile a minute—sometimes reaching two miles a minute.

Cirrus clouds may be produced in a variety of ways. They often occur with warm front activity far in advance of the surface position of the front. There is some question whether they actually occur in the warm front surface or in connection with high atmospheric activity above the front; but, whatever the cause, cirrus clouds are useful indicators of warm front activity. Cirrus clouds may form entirely unconnected with frontal activity when upward motions develop in the upper troposphere. They are particularly liable to occur just south of well-developed jet streams (in the northern hemisphere) and, in fact, certain cirrus cloud types are good indicators of jet streams.*

Cirrus clouds are usually found in the upper troposphere—seldom in the stratosphere — unless there should be a break in the tropopause.

Cirrus nothus, dense cirrus, are known to blow off the tops of a cumulonimbus cloud, carrying the remains of the frozen upper parts of that cloud. In the tropics, cirrus may cover most of the sky during thunderstorm activity.

The cirrocumulus is a feathery cloud, usually found in layers as much as a mile deep. This cloud formation is rather uncommon.

The cirrostratus is like a thin film, often covering the whole sky (figure 7). At times the cloud cover is so thin that it is hardly visible; othertimes, it has a fibrous structure, as shown in figure 8. Because this cloud cover contains ice particles, halos are usually visible around the sun or moon.

**George F. Taylor, Ph.D., Elementary Meteorology, Clouds and Fog, P. 173.*

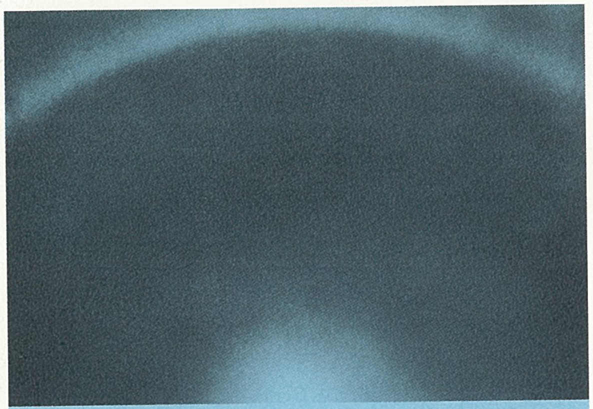


*Figure 7. Cirrostratus is like a misty veil covering the celestial dome. It does not hide outline of sun or moon. The presence of a halo implies an abundance of ice crystals, and this phenomenon distinguishes cirrus from haze aloft.*

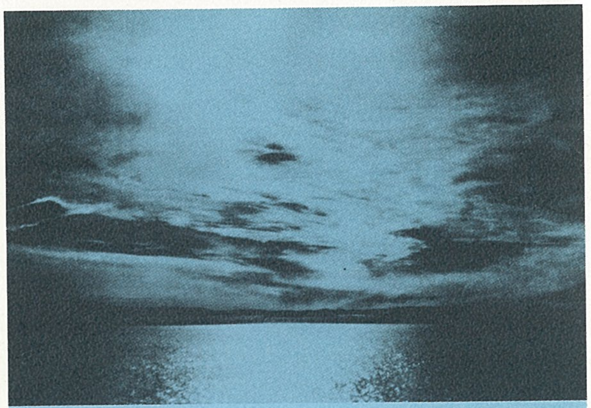


*Figure 8. Some cirrostratus clouds, as in the photo above, do not progressively invade the sky nor do they completely cover the sky. The dense fibrous structure of this cloud cover is not thick enough to cast shadows of objects on the ground.*

# Middle Clouds

Middle clouds occur at altitudes from 6,000 to 20,000 feet. Most of these clouds are composed of water droplets; a few of them may contain ice crystals. The altostratus translucidus (figure 9) is a thin cloud layer that often veils the sun or moon, making it faintly visible. Another form of this cloud is the altostratus opacus (figure 10). This cloud formation is variable in thickness and its gray or blue veil is generally dense enough to hide the sun or moon.

The altocumulus clouds are of many varieties. The altocumulus lenticularis, shown in figure 11 often occur at one or more levels. As they progressively invade the sky and thicken, they bring unstable conditions. These thickening clouds, known as the altocumulus translucidus undulatus, are formed in semitransparent bands or layers, as shown in figure 12. The altocumulus translucidus (figure 13) is made up of a layer, or patches, of slightly flattened globular masses. Blue sky shows through the interstices.

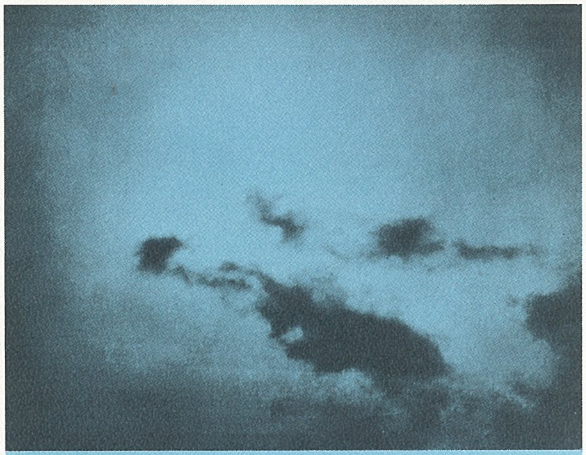


*Figure 9. Altostratus translucidus is a striated fibrous veil, gray in color, through which the sun or moon shines faintly. Small masses of low clouds are below the altostratus in this photo.*

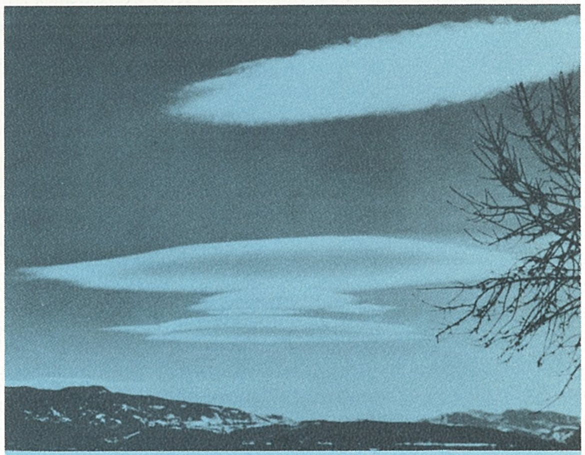


*Figure 11. Altocumulus lenticularis often resemble fishes. They occur at one or more levels and the elements are continually changing in appearance. They are somewhat transparent.*

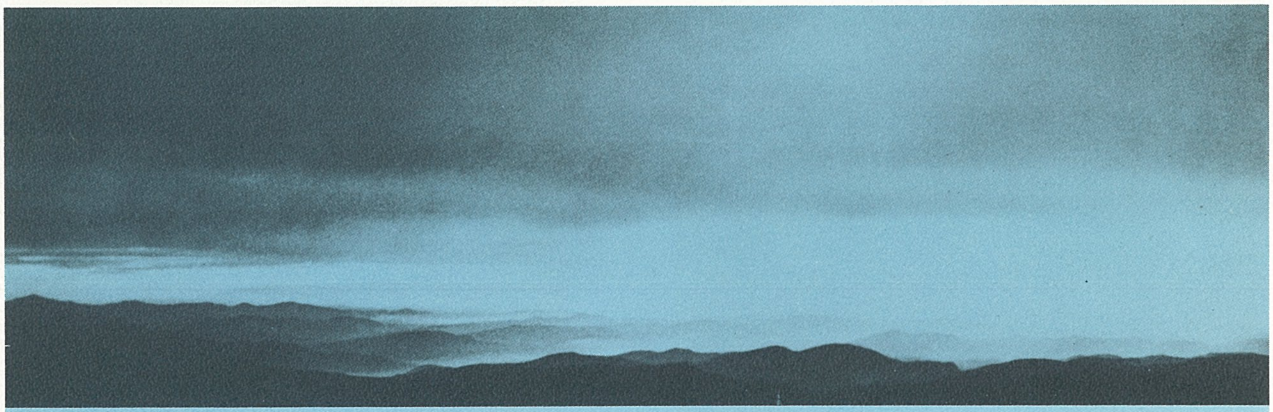


*Figure 10. Altostratus opacus is an opaque fibrous veil, gray or blue in color. Although its thickness is variable, it is usually dense enough to obscure the sun or moon.*

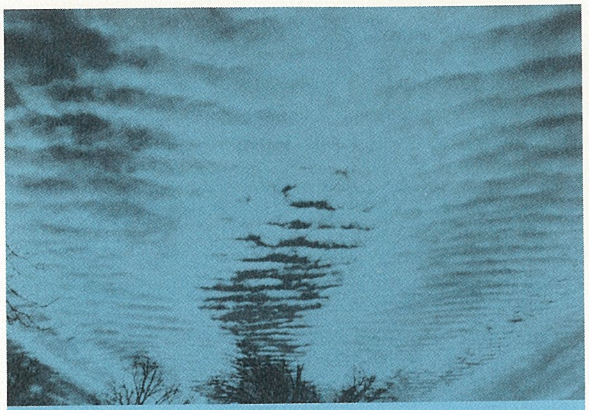


*Figure 12. Semi-transparent altocumulus translucidus undulatus are altocumulus in layers, with dark irregular elements that stand out in relief on the lower surface of the cloud cover.*

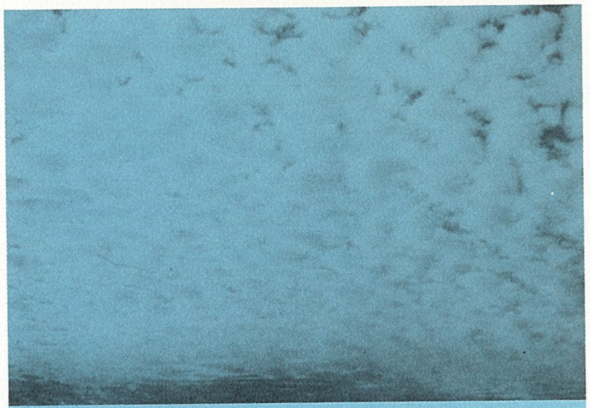


*Figure 13. Altocumulus translucidus are made of layers or patches of globular masses that are somewhat transparent. The various elements of the cloud change slowly. All are at one level.*

## Low Clouds

Low clouds occur in an altitude range from near the ground to 6,000 feet, below a temperature inversion where air is moist and, being activated, is carried up to the inversion. These stratus clouds (figure 14) are fairly thin and often several thousand feet deep. They resemble fog which, in fact, they are. (Fog is defined as a cloud that rests on the ground.)

Stratocumulus clouds are similar to stratus clouds in that they are also formed by temperature inversions. These clouds are usually broken up into separate small clouds—the stratocumulus cumulogenitus (figure 15). They are soft and gray in appearance with patchy dark areas, either in masses or layers. As they gently roll across the sky, they are very often called "fairweather" clouds, and are associated with local updrafts resulting from flow over rugged terrain.

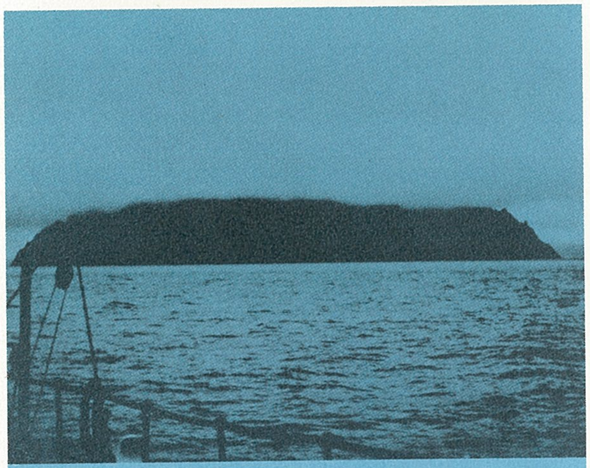


*Figure 14. The stratus cloud is a more-or-less continuous sheet, or layer, of cloud cover that is often several thousand feet deep. Usually called fog, it may or may not rest on the ground.*

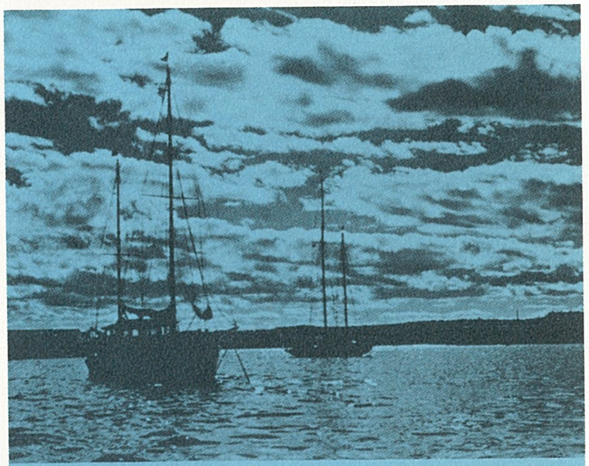


*Figure 15. Stratocumulus cumulogenitus are layers formed by the spreading out of the tops of cumulus clouds. In the first stages of development, they resemble the clouds in figure 12.*

# Vertically Developed Clouds

Clouds with vertical development extend from 15,000 to 20,000 feet. Figure 16 shows cumulus clouds of little vertical development. They usually are seen in fair weather. The cumulus congestus clouds in figure 17 have a distended and swollen appearance, the upper surfaces having dome shapes or cauliflower-like protuberances. Eddies which appear along the edge of violent air currents result in the cauliflower appearance on the outside of the cloud. When these vertical currents rise beyond the freezing level of the surrounding atmosphere, the cumulonimbus cloud may be developed, and a thunderstorm is likely.

As these clouds "boil" upward into an anvil shape and begin to darken, they are called the cumulonimbus (figure 18). In this boiling action, the atmosphere is manufacturing gusty winds, thunder and lightning, rain and, sometimes, hail.

The vertical growth of the cumulus cloud is due to an invisible rising column of air. Whether thunderstorms are caused by air being heated from below (air mass thunderstorms) or by air being forced up an inclined plane (frontal and orographic thunderstorms), they all have the same general characteristics. These strong updrafts of air, which are the basic cause of the thunderstorm, are offset by downdrafts, both within and outside the thunderstorm cloud. The result is severe turbulence, with the greater portion occurring ahead of the storm in the area known as the "roll cloud."

*These clouds should be given a wide berth.*

Cirrus clouds are usually found spreading upward from the anvil; at the base of the cumulonimbus are layers and patches of altocumulus clouds.

Cumulonimbus occurring in a storm front may not always be visible, because they can be masked by these other clouds. Low-level clouds may hide the roll cloud, the dark rain area, and the base of the actual thunderstorm. Multi-layer shelves of non-violent cumulus and stratus type clouds often extend for many miles in front of the thunderstorm, hiding its anvil top from low-flying aircraft or its base from an aircraft at altitude.

When the atmospheric freezing level is relatively close to the earth's surface, tops of clouds are generally low. Realistically, these clouds do not indicate a true thunderstorm but, rather, a rainshower. The formation generally lacks an anvil top and a well-defined or active roll cloud. The entire cloud has a cauliflower appearance with a slight veil of cirrus type clouds around the dome. These storm clouds may contain violent turbulence while they are developing, but gusts are of short duration and lightning is uncommon.

Thunderstorms that build up to 30,000 to 60,000 feet, however, are a different matter. The height to which these clouds extend is primarily governed by the distance between the earth's surface and the atmospheric freezing level.

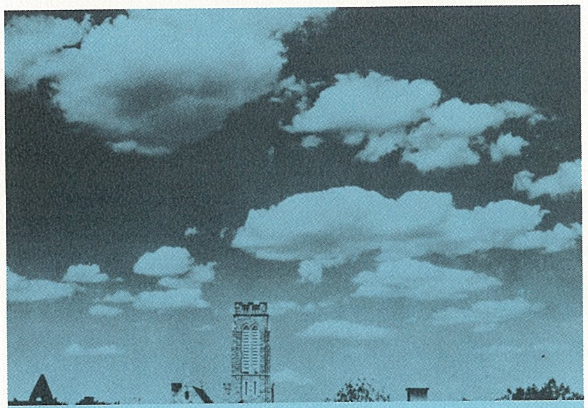


*Figure 16. Cumulus humilis have little vertical development and their tops are somewhat flattened. They are generally seen in fair weather.*

The most violent thunderstorm activity occurs in the lower two-thirds of thunderstorm clouds. If it is 30,000 feet from the base to the top of the cloud, the greatest turbulence can be expected in the lower 20,000 feet (see figure 19).

As mentioned earlier, thunderstorms have their origin in cumulus clouds, where the fundamental action is a strong upward current of air. As the atmosphere attempts to retain its balance and re-establish a stable condition, it is manufacturing gusty winds, and the air is rising, expanding, and cooling. If it cools

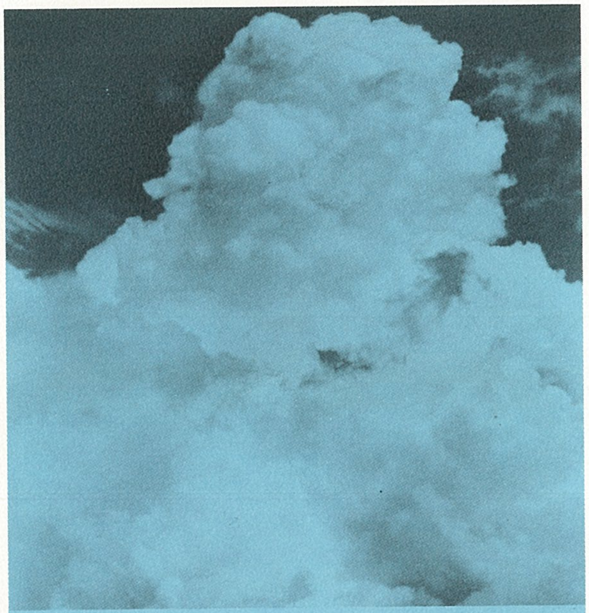


*Figure 17. Thick cumulus congestus clouds have moderate-to-strong vertical development, with protuberances in the form of domes or towers.*

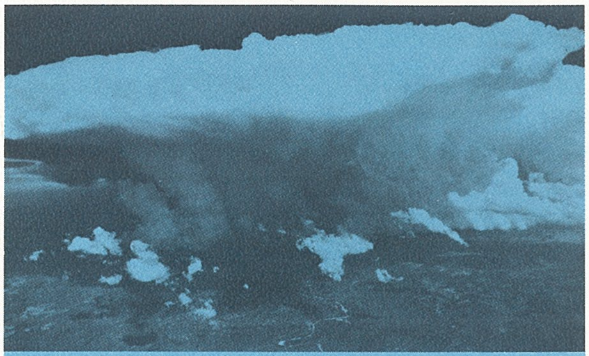


*Figure 18. Cumulonimbus are heavy masses of clouds with great vertical development. Upper structure is fibrous and generally spreads out in shape of an anvil. This photo is of a fully developed cumulonimbus (thunderhead) taken by an Air Force C-130 flying at altitute of about 30,000 feet. Top of the thunderhead is over 35,000 feet. The C-130, operated by the Geophysics Research Directorate of the Air Force, is one of several research aircraft probing storms in Weather Bureau's National Severe Storms Project.*

sufficiently, the moisture in it becomes visible in the form of a cloud.

These clouds are composed of minute water droplets; however, as they build up to the freezing level, some of the moisture in them turns into ice crystals. These water droplets and ice crystals, when agitated by air currents, form larger particles. As these droplets increase in water content, they reach a critical size at which the updraft can no longer sustain them, and they fall out of the cloud as precipitation. If they fall through temperatures above 32°F, they fall to the ground as rain.

It takes a sharp edge gust of 9 m/sec to disrupt a drop 3.5 mm in diameter. (This velocity is comparable to the updraft velocity in cumulonimbus clouds.) The effect of these drop disintegrations is to prevent raindrops from falling out of the updraft and to accumulate large amounts of liquid water in the cloud.*

When large raindrops are falling against the airflow in a strong upward current, they are blown to bits and the spray that results is carried aloft—the spray being lighter than the drops and therefore more readily airborne. In this process of breaking up, the raindrops produce positive and negative ions of electricity (see figure 20). Thus, in addition to moisture, the cloud now has a static electric charge. When this charge builds up sufficiently, it discharges from cloud to cloud or from cloud to ground in the form of lightning. Some researchers believe that electrical charges are in the air before the rain cloud develops; nevertheless, when these charges build up sufficiently, the effect is the same.

The updrafts of air ahead of the storm and the downdrafts within the storm cause a roll cloud to form at the base of the leading edge. Slightly ahead of this area on the surface, variable and shifting winds prevail. In and around the roll cloud is the region of maximum turbulence.

The following excerpt from a report by the British Ministry of Transport and Civil Aviation is based on actual flights in turbulence.

"Vertical air currents or drafts are the high columns of rapidly rising or descending air which comprise an integral part of the thunderstorm structure, and attempts to maintain a constant altitude in strong drafts may be a pilot's first step towards loss of control. Updraft velocities increase as height increases and . . . one aircraft flying at 26,000 feet experienced an upward displacement of 6,000 feet, though the maximum displacement on 90% of the flights was 2,000 feet. Down-drafts are usually not as strong as up-drafts, and their velocities diminish towards the lowest levels of the storm. They very seldom measure more than two or three miles across.

"With regard to the possibility of a down-draft forcing an aircraft into the ground or dangerously close to it, the lowest altitude flown during the USAF project, with a few exceptions, was 6,000 feet and there were no instances where the aircraft at this altitude lost more than 2,000 feet. The down-drafts subsided when the aircraft broke clear of the clouds underneath the storm. Whilst the intensity of down-drafts normally diminishes towards the lowest levels, it should be remembered that they can extend below

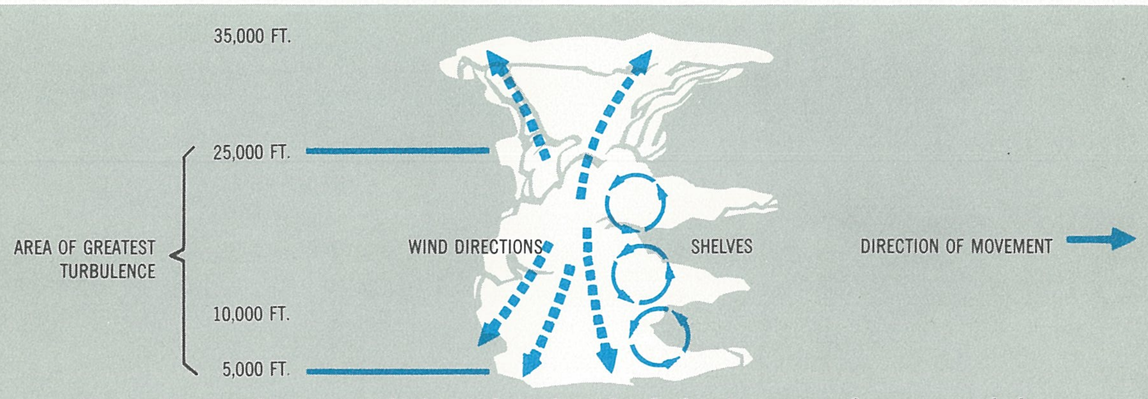


*Figure 19. Graphic portrayal of cumulonimbus cloud, showing areas of greatest turbulence.*

---

**Barry Mendoza, Meteorologist, GD/Convair* the base of the storm cloud and continue very close to the ground.

"Present knowledge is not considered sufficient to support any hard and fast rules regarding the minimum safe altitudes to be flown above the terrain in thunderstorm areas. There is a relationship between rainfall and down-drafts and a pilot encountering heavy rain beneath cumulonimbus cloud should expect to lose height.

"Severe turbulence appears to occur more frequently at some altitudes than at others. During both the United States and United Kingdom flight research, the best heights for avoiding severe turbulence were found to be below 10,000 feet. Turbulence appears to increase with height up to rather less than half the total vertical extent of the cloud, and then to remain about the same with increasing height until the top third of the cloud is reached where it decreases with height. This supports the advice frequently given to pilots entering cumulonimbus cloud to fly at the lowest possible height, though, of course, ample terrain clearance must be allowed. Acute bumpiness in thunderstorms has been found to be very localized and limited in duration. One aircraft may experience very severe turbulence while another aircraft a short distance away—either horizontally or vertically—or making the same traverse a short time before or after, may find nothing out of the ordinary."

The anvil top, which is above the turbulent activity of the storm, consists primarily of ice crystals. Hail forms in the chimney of the thundercloud at an altitude above the freezing level. After the hail has once formed, reports indicate it will overflow from the cloud at some point above the freezing level, and fall down the sides of the cloud in the surrounding clear air where there are no vertical currents to retard it.

Pilots have experienced heavy hail in the clear air outside a thunderstorm, which seems to support the theory that the worst hail is generally encountered around the main storm cloud and underneath the overhanging shelves, rather than in the region of the heaviest rain in the core of the storm.

It is possible for hail to fall to the ground when there is no indication on the ground of a thunderstorm. This can be explained by the fact that high winds may carry a hail mass into a clear area on the fringe of a thunderstorm.

Hailstones vary in size from that of a pea to a tennis ball. It takes a vertical current of air of approximately 100 knots (50 m/sec) to suspend a 10-cm diameter hailstone, and ordinarily the updrafts do not exceed 25 m/sec (50 knots).

There is no reliable method of recognizing, in advance, a thunderstorm which may provide hailstones. Experience to date shows that hail is encountered infrequently and that heavy hail is extremely rare. For example, in 87 penetrations made into tropical storms, hail was encountered seven times and was only once recorded as moderate to heavy. When it does occur, it appears that the region of hail and its duration in a storm are relatively small. Aircraft are known to have encountered small showers of hailstones up to three inches in diameter, sustaining only superficial damage, although on other occasions there have been instances of windscreens being holed and splintered. The risk of hail damage to aircraft, while not great, should not be ignored. The procedure to minimize the possible hazard of hail is to stay as far below freezing level as practicable and to hold the original course, since hail is usually a localized phenomenon. A high altitude, say 25,000 feet or above, offers the best alternative.

About 400 of the traverses made (and reported by the British Ministry of Transport and Civil Aviation) were carried out at temperatures below 0°C. In only five of these traverses was clear ice encountered and then it accumulated to less than $^{1}/_{16}$th of an inch. Wet snow packing on the leading edges of the wings was experienced during some 340 traverses, but did not build up to more than a quarter inch in thickness. At no time did airframe icing present a flight hazard to the Project pilots. Also during 500 miles of United Kingdom flight research in cumulonimbus clouds, difficulty was experienced on only two occasions. The first occurred at an early stage in the experiments and the flight was abandoned. On the second occasion, very heavy airframe icing took place during a flight of about 25 miles along a line of cumulonimbus at temperatures below freezing point. The probability of heavy icing undoubtedly exists if flight in cloud is prolonged at temperatures below zero. Carburetor icing proved more serious, the danger occurring between plus 18° C and minus 10° C outside air temperature. Pilots (of piston-engine aircraft) should be well briefed when to use carburetor heat.

Severe turbulence is the most frequent weather problem encountered by flight crews, but lightning can be the most startling and distracting. While many aircraft have been struck by lightning, there is little positive evidence of serious damage to metal aircraft by the strike itself, and the occupants are safeguarded by the aircraft bonding requirements.*

Lightning is usually the first warning of thunderstorm activity ahead. Lightning can often be seen in the distance, especially at night, before the storm shows up on the radar scope.

Of the many types of lightning strikes—those in clouds, beneath clouds, and between clouds,—the cloud-to-cloud strikes are the most apt to affect aircraft.

The region of the most frequent lightning flashes is ordinarily the most violent point within a storm. If more vertical than horizontal flashes are observed, it is an indication that the storm is being approached from the front, and there is greater violence. Conversely, if the flashes are more horizontal than vertical, the storm is being approached from the rear. If horizontal flashes are the only type observed, the storm is

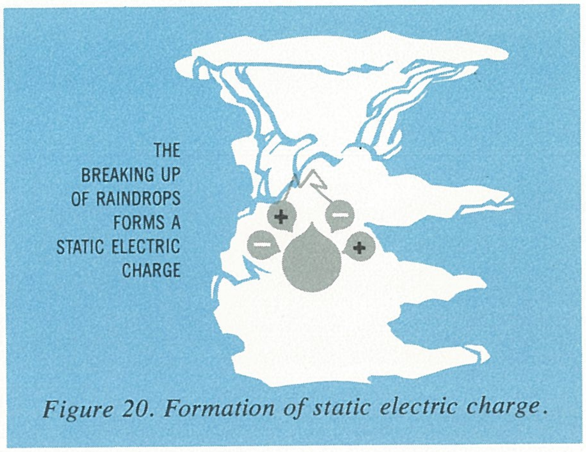


*Figure 20. Formation of static electric charge.*

---

**British Ministry of Transport and Civil Aviation.*

mild and its base is well above the surface of the earth.

When lightning strikes an aircraft, there is a blinding flash accompanied by a very loud explosion that has been variously described as a heavy artillery piece being discharged outside the cockpit, a sharp crack, or a thunderclap. A smoky odor (ozone) is usually noticed but no smoke is observed.

It is difficult to accurately tell where the lightning struck the aircraft. The copilot will be under the impression it struck the right wing; the pilot will believe it struck the left wing. The flash is equally brilliant on all sides, regardless of the actual point of contact.

The noise or concussion accompanying the flash may be loud and uncomfortable, causing acoustical shock and momentary dizziness and ringing in the ears; the pilot's ears may hurt for several minutes, and he may become momentarily deaf. Lightning may also cause a current surge in the radio circuit, and its effect will be noticeable by a sharp crack in the earphones. In addition, St. Elmo's fire will produce a continuous high-pitched grating sound in the earphones.

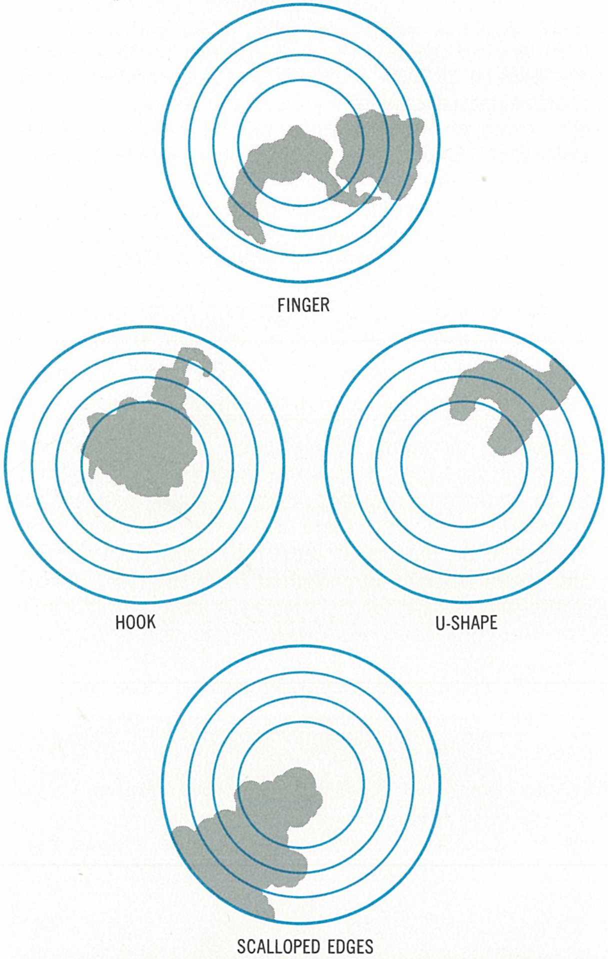


*Figure 21. Weather as it appears on the radarscope. Shown in drawings are areas to be avoided.*

Because of the blinding flash and the deafening noise, the pilot may have the impression that the aircraft is "becalmed"—there appears to be no engine noise and the airplane seems to be soundlessly suspended in the air. This effect is a result of temporary impairment of sight and hearing. The sudden flash and resounding crash accompanying the lightning strike may have a tendency to startle the pilot for an instant, producing temporary confusion, and his reactions may be slow and faulty.

There are several things the pilot can do to minimize the effects of a lightning flash or strike.

First and most important is to avoid areas of thunderstorm activity. Watch radar scope continuously; avoid by 10 miles all echoes with fingers, hooks, scalloped edges, or U shapes (see figure 21).

When flying in areas of lightning at night, it is recommended that all cockpit lights be turned to full bright intensity to reduce the effects of temporary lightning blindness.

Wearing a visored cap to shield the eyes will help to minimize the flash.

In all cases, it is recommended that the pilot keep his eyes focused on the instrument panel so that his eyes will be shielded somewhat from a direct flash.

Earphones with protective devices should be worn, and earphones should be loosely fitted. If desired, a handkerchief, or other padding, may be worn between the ears and receivers to lessen the acoustic disturbance.

Use of autopilot will leave the pilot free to monitor instruments and controls, the autopilot maintaining control during those few seconds when atmospheric electric discharges could momentarily confuse crew members. With autopilot on, the "Altitude Hold Mode" should be off. The autopilot, however, should not be engaged during severe turbulence. In moderate-to-severe turbulence, the autopilot, too, would require monitoring because encounter with severe turbulence could put the airplane in an attitude from which it would be difficult to recover. In other words, the autopilot should be used only in light-to-moderate turbulence, the decision to be made at the discretion of the flight captain. When autopilot is off, the yaw damper should be engaged, after rudder is trimmed and centered. Engine thrust should be stabilized and maintained at the recommended airspeed/Mach number, and it should not be changed except in case of extreme airspeed variations.

Careful planning prior to penetration of a possible thunderstorm area is important. When encountered in flight, thunderstorms and other related areas of turbulence should be avoided by any of the following methods: circumnavigation; flight below the base of the storm, if a terrain clearance of 3000 feet can be maintained; "over the top"; and a precautionary landing that can be made until the thunderstorm passes.

The life cycle of a thunderstorm cell is from two to three hours, and may extend from one to five miles in diameter; however, other cells forming near, but separate from, the main cell, could develop to major proportions. Individual

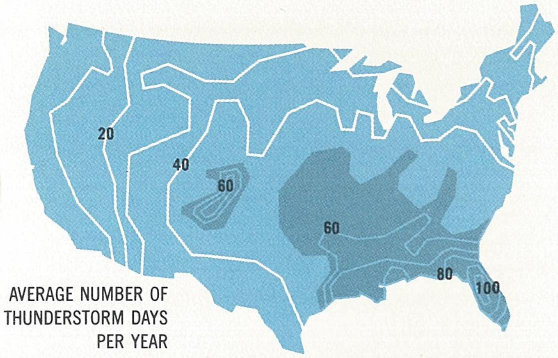


*Figure 22. In the United States, the greatest number of thunderstorms are found in the southeast, as indicated on the map. July and August are the months of greatest thunderstorm activity.*

cells may be in any stage of development, but the majority in a storm are either at peak or dissipating stages. The cells in the developing or peak stage and their boundaries are the areas of greatest turbulence. It is important to realize that the greatest turbulence may be experienced before lightning or thunder occur. In fact, lightning in cumulonimbus may be an indication that the storm has passed its peak. There is no sure method at present of finding the safest way through a storm area, but limited experience with airborne radar indicates that it can be expected to reveal the majority of centers of severe turbulence. It has been found that the visual appearance of a cloud does not permit an estimate to be made of the degree of turbulence likely to be encountered. The tops of thunderstorms may be as low as 10,000 feet in temperate latitudes, but are usually very much higher and may reach above 40,000 feet on occasion. In the investigation in the tropics, the measured tops of the clouds penetrated were usually above 40,000 feet and on one occasion reached 55,000 feet.*

The safety and comfort of passengers and crew will depend upon the course of action the pilot will take. The following pertinent conclusions may assist him in making this decision.

- When encountering cold-front thunderstorms, or other extended lines of thunderstorms, where individual thunderheads are separated by clear areas within accessible altitudes, flights can be conducted in reasonable comfort through these clear areas and above the lower level of clouds. *Do not fly closer than 2500 feet to the cumulonimbus buildups.*
- Do not fly in the immediate vicinity of a thunderstorm or a line of thunderstorms, when below an intermediate level overcast. Thunderstorms have a tendency to expand above stratus type clouds and may release heavy rain or hail outside the actual thunderstorm itself. Severe turbulence may also be encountered because of the instability of the air in the thunderstorm area.
- Exercise care when descending toward a thunderstorm with the intention of flying below its base. The normal glidepath of the airplane may be increased by down-drafts, and the rate of descent and indicated airspeed may increase beyond limits. Such descents should be conducted at greatly reduced airspeeds.
- Never fly under the overhang of the cumulonimbus. This is the area of severest hail fall.
- Never attempt to fly through a squall line or cold front thunderstorm unless positive knowledge is had that the individual squalls are loosely connected and can be safely circumnavigated, or unless it is definitely known that flight can be conducted between the build-ups and above the tops of all lower level clouds. Squall lines usually occur in the spring, and east of the Rocky Mountains, when cold air from the North contacts the warm air from the Gulf.
- Before entering a suspected thunderstorm area, switch gyrosyn compass to directional gyro position and set just before penetration. If the aircraft should receive a strike, the gyrosyn compass in D-G mode will be fairly accurate, although other directional instruments may be unserviceable. Even in relatively severe turbulence, the gyrosyn compass generally will not precess excessively and will provide a reliable measure of directional indication.
- If at all possible, avoid flight through clouds at levels where ambient temperatures range between +15° and −10°F (-9° to -23°C). Under such conditions, potential gradients and resulting disruptive static charges can be expected.
- Avoid flights in the immediate vicinity of the cumulonimbus cloud, especially when there are indications of thunderstorm activity. It is preferable to keep at least 2500 feet or more away from the cumulonimbus.

Avoid cirrus clouds if thunderstorm activity is reported anywhere in the vicinity. The clouds could be hiding the thunderhead.

- Avoid flight through moderate or heavy rain and/or snow, hail, or ice crystals, especially at levels where the temperature is 20° to 40°F (-7° to +15°C), particularly if the precipitation is from a cumulonimbus.
- If precipitation static and/or Corona discharge (St. Elmo's fire) is moderate to severe, and there is evidence from the temperature, cloud, and precipitation conditions that the aircraft is in a zone of strong potential gradient between oppositely charged regions, seek a lower level where temperatures above 40°F prevail, or leave the given cloud and precipitation conditions. The tendency for precipitation static to increase rapidly in intensity should be regarded as a reliable indication that a lightning discharge may be imminent.
- Altimeter and rate-of-climb indicators may give faulty readings, but these readings will not be operationally significant. This is due to rapid pressure variations that accompany a thunderstorm.
- Remember – Lightning strikes occur more frequently below 10,000 feet and rarely above 20,000 feet.

Although all possible precautions are taken in the design of pitot heads, there is a possibility that heavy rain may cause an airspeed indicator to read low. It is considered that any liability to error may be reduced by the use of pitot heaters. If, in cruising flight, the power has been selected which gives the safest speed before the storm is entered, any fluctuation in the airspeed readings can be disregarded, provided that a reasonably level attitude is maintained.

---

**British Ministry of Transport and Civil Aviation.*

# Inspection After Flight Through Thunderstorm Activity

Whenever an aircraft has encountered thunderstorm activity, it should be thoroughly inspected for lightning strike damage—both obvious and obscure. Major damage from a lightning strike is not always at a known point of impact, or entry; and, it is even possible for the airplane to receive a lightning strike resulting in damage, without the knowledge of the flight crew.

Lightning will enter at one point on the airplane and be discharged at another point, usually from some extremity such as the rudder, elevators, wing tips, or radome. Major points of entry are the antennas and the radome, which attract and lead lightning into the cabin where it can damage navigation and transmitting/receiving equipment. Magnetic compasses, after a lightning strike, are usually unreliable because of the magnetic charge, and require reswinging.

At the impact point, skin damage will usually result in small patches of discoloration or scorching, and/or some fusing of rivet heads. Some pitting may also be noticed, but most pitting will be at the discharge point. Since it isn't always possible to determine the point, or points, at which the current was discharged, a thorough inspection will be required.

Following are the areas to be inspected whenever the airplane has encountered damaging thunderstorm activity.

12 54

## Radome

1. Check lightning arrestor strips for burn damage; clean area and replace strips if they are discolored or burned.
2. Inspect interior and exterior surfaces of radome for damage in the form of pin holes and/or burns. After cleanup and repair, make functional check of radar system.
3. Inspect radar equipment—antenna scanner and mounting structure. If damage is noted, bench-test equipment for transmission, reflection, and absorption characteristics.
4. Inspect glidepath antenna for pitting and discoloration. Replace antenna if damaged, and perform operational check on glidepath system.
5. Inspect microwave absorber and replace if damaged.

## Flight Compartment

1. Check magnetic compass. If it is magnetized, check nose landing gear for magnetization, and demagnetize if required. Reswing compass.
2. Check radio equipment; if antennas have been damaged, radio may be inoperative.
3. If radar scanning antenna in nose radome has been damaged, check receiver-transmitter, waveguide, and accessory unit in cockpit.
4. Perform operational checks as required.

## Landing Gear

1. Check steel landing gear for magnetization. If nose gear is magnetized, it could affect operation of instruments—especially of the magnetic compass—and must be demagnetized.

## Fuselage

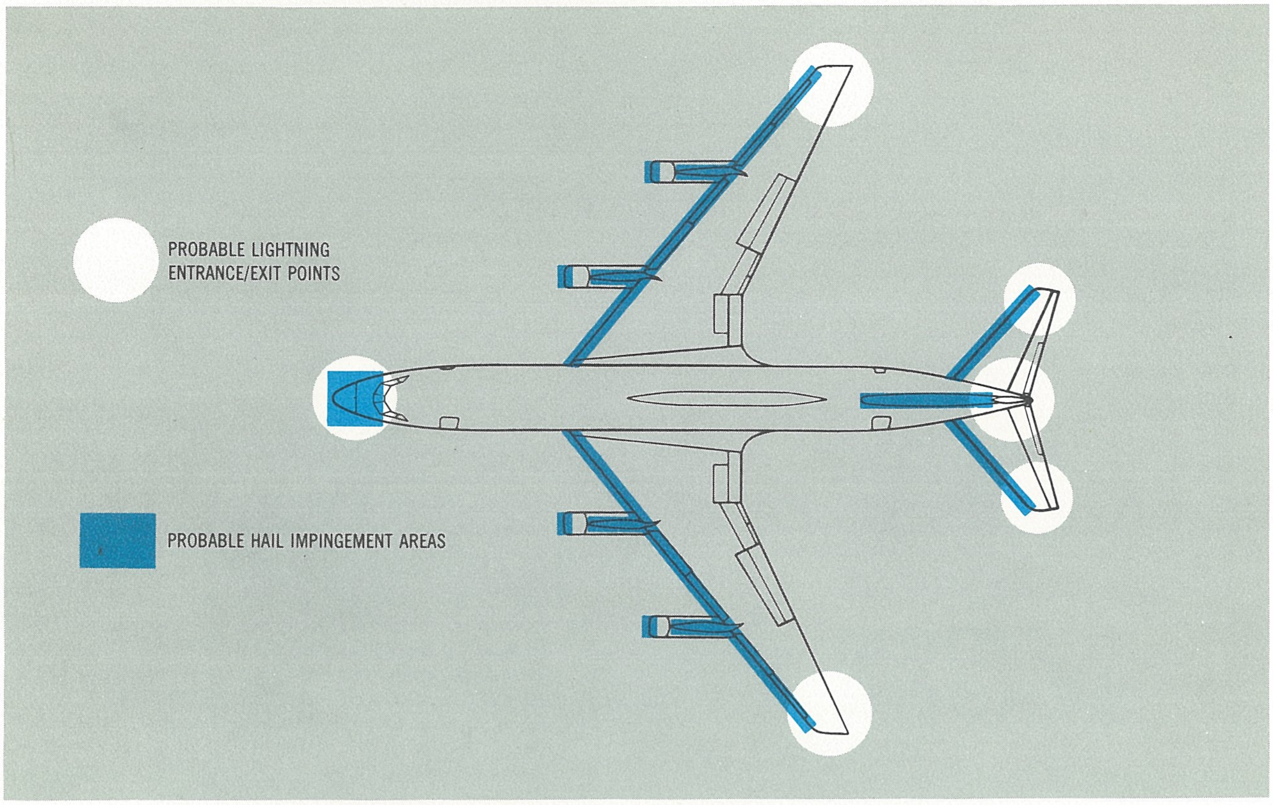
1. Inspect complete fuselage skin, especially along the lower area, for discoloration, burn marks, fused rivets, and discharge holes and pitting.
2. Inspect all antennas for damage. If damage is found, make complete operational check of system.
3. Inspect tail cone light for damage and operation.
4. Check pitot masts aft of nose radome for pit marks and burn damage. Damage to pitot masts could cause malfunction of airspeed system.
5. Inspect tail cone lights for damage.

## Wing

1. Inspect wing tips for damage and burn marks.
2. Check wing tip lights, and make functional test of lighting.
3. Inspect pylons and pods for pitting and burns. Check pod hinges for damage.
4. Check flaps, ailerons, and spoiler panels for damage. Check operating mechanisms of control surfaces.
5. Check static dischargers and replace if damaged.

## Empennage

1. Inspect tail surfaces for burns and fused rivets.
2. If damage has been incurred in the areas of the HF and VHF antennas on the vertical stabilizer, thoroughly check antennas for damage.
3. Check elevator, rudder, and tabs for damage to the skin surfaces and hinges.
4. Inspect static dischargers for damage, and replace if necessary.


PROBABLE LIGHTNING ENTRANCE/EXIT POINTS
PROBABLE HAIL IMPINGEMENT AREAS

12 54

## Hail Damage

If the aircraft has encountered hail, the most likely areas of damage will be on the nose radome, engine pod inlets, and wing and empennage leading edges. Repairs to the radome should be made in accordance with information in the Convair Traveler, Vol. VIII, No. 3, dated July 1961; or Newsletter, Vol. V, No. 4, dated 15 July 1964.

For minor repairs to the metal wing leading edges, some operators use a filler material, such as MET-L-IT. All dents, $^{3}/_{16}$ inch deep or less—if they are inaccessible from behind for hammering out—may be filled with this material; however, it should be remembered that MET-L-IT is a low heat conducting material and heat anti-icing will be impaired.

Following are instructions for applying this material.

1. Thoroughly clean the surface to which MET-L-IT is to be applied.
2. Roughen surface of metal to ensure good adhesion.
3. With a putty knife, or similar tool, apply MET-L-IT to the surface of the dent in layers approximately $^{1}/_{16}$ inch in depth, allowing each layer to harden before the next layer is applied. Apply the last layer slightly above the surface of the leading edge. Do not run the putty knife back and forth over the surface of the MET-L-IT because this will tend to pull the compound from the leading edge.
4. Work the MET-L-IT to the same contour as the leading edge by first removing the excess MET-L-IT with a hand file or power sander, and then smoothing the surface with emery paper. A hand file should be used for small areas; a power sander for large areas. In either case, care must be taken to prevent striking the metal skin with the tool.
5. Brush-coat a thin layer of MET-L-IT, thinned with MET-L-IT solvent, over the sanded surface to obtain a smooth finish.

**Caution**

When working with MET-L-IT, keep it and all surfaces free from grease, and avoid touching it with the hands during application.

MET-L-IT and the MET-L-IT solvent may be obtained from R. M. Hollingshead Corp., Camden, 2, New Jersey, U.S.A.

If heating elements on elevator and rudder leading edges are damaged, repair in accordance with procedures in the Structural Repair Manual.

# T-STORM SEASON

12 54

It's thunderstorm time again, and also time to refresh our memories concerning the Do's and Don'ts of operations in and around T-storm areas. As repetitious as the words may seem, accident records indicate a need for reminders that the hammer of Thor can strike a mortal blow, particularly to the unwary or careless.

---

## Preflight

1. Check closely with station meteorologist and Weather Bureau re the current and forecast locations of severe weather. Check the SIGMETS.
2. Check the aircraft's static eliminators. Make certain they are of proper length and that the wicks are not worn off or contaminated with oil or grease.
3. Make sure airborne radar is operative. It's a key tool in thunderstorm avoidance.
4. NEVER take off and climb into a thunderstorm.

---

## En Route

5. Keep up-to-date on the over-all T-storm patterns.
6. Remember that in the summer seemingly insignificant fair-weather cumulus can become dangerous monsters in a matter of minutes.
7. The most dangerous are those clouds with fastest growing tops.
8. If there's a lot of lightning, it's probably a wicked storm.
9. Use your radar:
   a. Intense echoes and echoes with sharp or scalloped edges indicate heavy rain, possible hail, and turbulence. (Studies have shown that the most turbulence occurs with heavy rain—and heavy rain and hail give the strongest radar precipitation echoes.)
   b. Reduce the gain; the last echoes to disappear are probably the most intense and the area surrounding these "hard core" echoes is apt to be the most turbulent.
   c. Areas between strong echoes usually are considered the least hazardous. BUT—remember that other T-storm cells may be obscured by the cells nearest you, and there can be turbulence in a cloudless area.
10. If you can't climb above the storm or circumnavigate it, use your radar to locate the weak spot in the line and go through at a 90° angle to the line.
11. Circumnavigation of a T-storm is preferable at the highest level; if high-level circumnavigation is not possible, the second best level is at 10,000 feet or below, and below the cloud base if terrain clearance is adequate.
12. Avoid flight at or near the freezing level; here is where hail is most likely to be encountered; ditto static electricity discharges.
13. If you have to go through the T-storm area, select a flight level other than at or near the freezing level; turn cockpit and cabin lights to high intensity; and slow the aircraft to the best penetration speed (as prescribed by the operations manual).
14. If you have no radar and thunderstorms are a problem, ask for flight-following assistance from FAA.
15. Remember that the most turbulent area is usually throughout the middle third of the vertical cloud structure.
16. Remember, too, that the heaviest icing is associated with air temperatures of 0° to −10°C.

---

## Landing

17. Never attempt a landing in a thunderstorm or if one is in the immediate vicinity of the airport. Get help from air traffic control to make certain your letdown and approach do not take you into a storm. Either delay your approach or proceed to an alternate rather than attempt to penetrate a thunderstorm on letdown and landing.

*Reprinted from Flight Safety Foundation bulletin, dated 15 June 1961.*

GENERAL DYNAMICS | CONVAIR